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Digital transformations in developing economies: From the first-mile infrastructure to the end-user finger tips

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Digital Transformations in Developing Economies From First-mile Infrastructure to End-user Fingertips

Joël Cariolle

WIPO

Digital transformations in developing economies: From the first-mile infrastructure to the end-user finger tips

Joël Cariolle

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Abstract

This paper reviews the concepts, mechanisms, and empirical evidence on the diffusion of digital technologies (DTs) in developing economies, focusing on the distinct infrastructural layers of connectivity—from first-mile submarine cables to last-mile mobile and broadband networks. It examines how infrastructure gaps, usage disparities, and technological divides shape digitalization pathways and their socio-economic impacts, with a particular emphasis on lower-income regions like Sub-Saharan Africa. The analysis highlights how submarine cables reduce connectivity costs and expand Internet access, yet also reveals uneven benefits due to limited absorptive capacity and new digital vulnerabilities. By synthesizing evidence on rural mobile coverage, urban Internet spillovers, and trade integration, the paper emphasizes the need for coordinated policies to bridge digital divides and foster inclusive digital transformation.

Key words: digital technologies, connectivity, internet, mobile, infrastructure, submarine cable, mobile networks, Africa.

JEL Codes: O14, O33, L96, O55, F63

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Acronymes

Artificial Intelligence (AI)
Broadband (BB)
Difference-in-Difference (DID)
Digital Financial Services (DFS)
Digital Technologies (DTs)
Economic Complexity Index (ECI)
Europe and Central Asia (ECA)
East Asia and Pacific (EAP)
General Purpose Technology (GPT)
High-Income Country (HIC)
Information and Communication Technology (ICT)
Interactive Voice Response (IVR)
International Standard Industrial Classification (ISIC)
Internet Exchange Points (IXPs)
Internet of Things (IoT)
Internet Service Provider (ISP)
Latin America and the Caribbean (LAC)
Low-Income Country (LIC)
Middle-East and North Africa (MENA)
Middle-Income Countries (MIC)
Mobile Money (MoMo)
Research and Development (R&D)
Small and Medium Enterprise (SME)
South Asia (SA)
Submarine Cable (SMC)
Sub-Saharan Africa (SSA)
Unstructured Supplementary Service Data (USSD)
West African Economic and Monetary Union (WAEMU)

1. Introduction

Digital technologies (DTs) have become central to contemporary debates on development, offering unprecedented opportunities to overcome structural barriers to information, communication, and financial inclusion. In both developed and developing countries, DTs have become critical drivers for growth, but their impact rely on their diffusion among individuals, firms and administrations. Diffusion is key since, on the one hand, DTs are network goods, that is, the marginal utility or effect related to their adoption depend on the size of the user network; and on the other hand, and they are general purpose technologies spreading across sectors, generating spillovers when digital technologies, knowledge and innovations spread across workers, firms, and industries.

The extent of DTs diffusion is intrinsically related to the notion of digital divide. This divide depends on the coverage of digital infrastructures, such as the mobile network or fiber optic landlines, on the telecommunications and innovation potential embedded in related technologies, and finally, on the capacity of their intended beneficiaries to adopt and use them properly. However, understanding the scope of the digital divide and the potential of DTs' diffusion process requires careful clarification of the underlying concepts and mechanisms through which DTs operate and spread. This introductory section lays the conceptual foundation for analyzing digital diffusion by unpacking the key definitions and functions of digital technologies, and by emphasizing their dual nature as both catalysts of efficiency and vehicles for socio-economic inclusion.

The first subsection defines key concepts that will be mobilized across this chapter, distinguishing between digitization and digitalization, and explaining the functional value of DTs. The second subsection attempts to delimit the scope of the digital economy and draws general trends in developed and developing economies.

1.1 Key concepts

1.1.1. Digital technologies, digitization, and digitalization

Transformations induced by the diffusion of DTs in developing countries involves distinct but interrelated concepts that deserve clarification. Three terms— digitalization, digitization, and digital technologies—are frequently used interchangeably but refer to different dimensions of the digital transformation process.

Digital technologies constitute the physical and virtual systems that enable both digitization and digitalization. They include a range of devices—such as mobile phones, smartphones, computers, tablets, radios, and beepers—and the infrastructures and protocols that support them (e.g., mobile networks, USSD, IVR systems, digital platforms). Moreover, digital technologies facilitate a wide array of functions, from communication and information dissemination to data collection, financial transactions, and content creation.

Digitization, refers to the technical process of converting analog content—such as sounds, images, text, or physical records—into a digital format composed of binary code. This transformation, made possible by DTs, enables data to be stored, processed, and transmitted electronically, thereby serving as a prerequisite for many forms of digital innovation. For example, the conversion of printed government records into digital databases or the encoding of voice into mobile signals illustrates core digitization processes.¹

¹ Digitization is therefore the process underlying the production of digital goods and services. **Digital goods** refer to intangible products delivered electronically. These include software packages, mobile applications, digital audio and video content, e-

Digitalization encompasses the broader socio-economic integration of digital technologies and resulting digitization process into everyday activities, services, and transactions. It describes how individuals, firms, governments, and societies increasingly rely on digital tools and infrastructures to communicate, access services, make decisions, consume and produce. This includes, for instance, the shift from in-person to digital banking, the use of mobile platforms for agricultural market access, or the deployment of e-government services. Hence, digitalization is both the consequence and a catalyzer of digitization and digital technologies diffusion.

1.1.2. Digital technologies as information and financial engines

Beyond their technical components, DTs serve as powerful engines for transforming how information and financial resources are accessed, processed, and exchanged. In developing countries—where information asymmetries, high transaction costs, and limited financial infrastructure have historically constrained development—DTs offer new avenues to reduce inefficiencies and expand inclusion.

As information engines, DTs play a central role in reducing the costs associated with the production, replication, and dissemination of information. Their deployment lowers several categories of economic costs (Goldfarb & Tucker, 2019; Aker & Cariolle, 2023), including:

- **Information search costs**, by enabling faster and broader access to relevant data;
- **Replication costs**, as digital content can be duplicated at near-zero marginal cost;
- **Transportation costs**, since information no longer requires physical movement;
- **Collection, processing, and storage costs**, due to automation and data compression; and
- **Targeting and tracking costs**, by leveraging digital footprints and user metadata.

In low-income countries (LICs), access to digital technologies mostly relies on the mobile infrastructure. The rapid spread of mobile phones—particularly feature phones with basic connectivity—has played a critical role in enabling these cost reductions. This deployment has been particularly impactful where transport infrastructure network remains limited, mobile connectivity facilitating real-time access to market prices, health information, educational content, and public service announcements, for landlocked and underserved populations.

As financial engines, mobile phone diffusion has spurred the development of digital financial services (DFS) that broaden access to savings, payments, credit, and insurance for unbanked populations. The first wave of DFS—exemplified by mobile money (MoMo) platforms—allowed users to send, receive, and store money securely using basic mobile phones, without the need for Internet access and a traditional bank account. These systems have significantly reduced the cost and geographic barriers to financial transactions, especially for rural and low-income populations.

More recently, MoMo platforms have evolved to support a second generation of DFS, including mobile-based digital credit, savings, and microinsurance products. By generating user-level data on financial behavior, social networks, and mobility patterns, DTs help bridge the information gap between unbanked populations and formal financial institutions (Aker & Carroll, 2022; Suri et al., 2023).

In sum, DTs are not merely conduits of communication—they are instrumental in reshaping how individuals and firms access and exchange information, but also engage in financial and

books, and other forms of downloadable or streamable media. **Digital services** encompass a broader range of activities delivered remotely through digital channels, including business process outsourcing (BPO), IT-enabled services (ITES), data storage and processing (e.g., cloud computing), online education, digital consulting, and creative services.

economic transactions. DTs therefore are both information and communication technologies (ICTs) and financial technologies.

1.1.3. Digital technologies as general-purpose technologies and network goods

DTs possess two defining characteristics that make their diffusion central to their economic impact. Firstly, they are **general-purpose technologies (GPTs)** in the sense of Bresnahan and Trajtenberg (1995): pervasive across sectors, subject to continual technical improvement, and generating innovational complementarities. Advances in the core technology raise the returns to complementary innovations in user sectors—such as new applications, services, and production methods—which in turn create further incentives to improve the technology itself. This reciprocal dynamic means that the benefits of DTs depend not only on the technology's sophistication and impact, but also on the capacity of firms, workers, and institutions to adapt and innovate around it.

Secondly, DTs are **network goods**: their utility to each user rises with the number of other users in the network, as shown for instance in the Rwandan context (Bjorkegren, 2019; Bjorkegren & Karaca, 2022). Adoption triggers network effects, whereby wider usage increases the value of participation for all—expanding market size, encouraging the creation of complementary products and services, and facilitating richer information exchange. In Rwanda, Bjorkegren (2019) models the rollout of mobile phones as a network good and estimates that adoption benefits increase sharply as more people join the network, creating a “critical mass” threshold beyond which uptake accelerates.

The interconnected nature of GPTs and network goods gives rise to **spillover effects** generating economy-wide benefits even before universal uptake is achieved, through innovation complementarities, vertical and horizontal externalities, and network effects

- **Innovational complementarities:** As a the GPT improves, R&D productivity in downstream sectors rises, amplifying innovation throughout the economy. For example, advances in semiconductor technology have driven successive waves of complementary innovations in personal computers, smartphones, and other smart devices.
- **Vertical externalities:** These occur between the GPT sector and its application sectors. Innovation in one side of the relationship produces benefits for the other that are not fully captured through market transactions. For instance, expanding mobile network coverage reduces the costs of placing and receiving calls, increasing call durations and utility, which can influence adoption and usage decisions across the network. In such cases, both the GPT provider and application sectors have weaker private incentives to invest than is socially optimal.
- **Horizontal externalities:** These link different application sectors. When more sectors adopt a GPT, the commercial potential of the GPT expands, encouraging further investment in the core technology. However, each sector tends to invest less than socially optimal because it does not internalize the full benefit its adoption creates for other sectors.
- **Network effects:** The expansion of network goods generates benefits that extend to indirect beneficiaries or users. In Rwanda, Bjorkegren (2019) finds that roughly 77% of revenue and 78% of welfare gains from a rural mobile network expansion accrued to

individuals whose personal coverage was not significantly improved. Similarly, in a mobile phone subsidy program, non-recipients accounted for up to 65% of the increase in operator revenue and 25% of total consumer surplus, solely due to spillovers from increased calling with subsidized users.

Table 1.1 below provides more details on the principles, mechanisms and actors involved in these spillover patterns. The interplay of GPT features, network goods and spillover effects has various implications for digital diffusion. First, these dynamics imply that the private adoption decision often underestimates the full social value of the technology, and that scaling up access—both geographically and socially—is essential for unlocking the full socio-economic gains of DTs. Second, the type of network infrastructure and the socio-economic environment shape which technologies scale. In low-income or rural areas, mobile networks often support the mass adoption of relatively simple, low-bandwidth services, while high-speed fixed broadband in urban centers enable the uptake of advanced, data-intensive applications such as cloud computing or AI tools.

Recognizing DTs as both GPTs and network goods also helps frame the broader digital economy discussed in the next section. Because these technologies cut across sectoral boundaries and their value depends on interconnected adoption, the frontiers of the digital economy are permeable: innovations in one domain can quickly spill over into others, and constraints in infrastructure or usage in one segment can limit opportunities elsewhere.

Table 1.1. Digital spillovers: principles, actors, and mechanisms.

| Concept | Source of spillover (who acts?) | Target of spillover (who benefits?) | Role of GPT solution (the core general-purpose technology) | Role of GPT sector (firms producing / supplying the GPT & infrastructure) | Example | Incentive issue |
|---------------------------------------|-----------------------------------------------------------------------------|--------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Innovational complementarities | Improvements in the GPT solution (e.g., better chips, better models) | R&D performers in downstream sectors | GPT becomes more powerful / versatile, raising the productivity of downstream R&D (e.g. more computing power, better algorithms). | GPT sector may invest in improving the core tech, but does not fully monetize all induced innovation in other sectors. | More advanced semiconductors → more powerful PCs/smartphones → explosion of complementary apps and devices. | Both GPT producers and downstream sectors under-invest in R&D because they don't internalize cross-sector innovation gains. |
| Vertical externalities | Investment/innovation by the GPT sector or application sectors | GPT application sectors in the same value chain | GPT is the interface through which the two sides interact (e.g., telecom standard, infrastructure technology, AI API). | GPT sector builds, maintains, and prices the core GPT solution (networks, platforms, models) used by applications. | Mobile operators expand mobile internet coverage (GPT sector), call costs fall, inducing more usage and higher value for users and complementary services, such as social media (application sectors). | Each side under-invests because it doesn't capture the full benefit it creates for the other side. |
| Horizontal externalities | Application sectors adopting and investing in GPT-based solutions | GPT and application sectors in different value chains | GPT becomes more valuable as more use cases and complementarities are discovered across sectors. | GPT sector's market expands as more industries adopt, increasing potential scale and learning-by-doing. | Adoption of a core AI or cloud platform used in finance, health, manufacturing, etc., increases the platform's viability and feature set for all sectors. | Each sector under-invests less than socially optimal because it doesn't internalize the benefit its adoption creates for others (or for the GPT sector's scale). |
| Network effects | GPT solution's direct beneficiaries or users | Indirect beneficiaries or non-users | GPT-enabled network good (e.g., mobile network, digital platform) generates external benefits via connectivity, information spillovers, and matching. | GPT sector (e.g., mobile operator, platform provider) generates extra revenue from indirect users or beneficiaries | Mobile network externality: increased welfare accrue to people whose own coverage barely changed, via calls with newly connected mobile users. | Large social gains to non-users / indirectly connected users imply private investment falls short of the social optimum. |

1.2. The digital economy

The general-purpose and networked nature of digital technologies means their benefits and spillovers extend well beyond their immediate applications. These technologies not only enable communication, information exchange, and financial inclusion—they also underpin a broad and evolving set of activities that make up the digital economy. Because DTs cut across sectors and their value increases with interconnected adoption, the boundaries of the digital economy are inherently permeable. They encompass industries directly involved in manufacturing ICT equipment, producing digital goods (e.g. streaming music, software) and providing digital services (e.g. cloud computing, e-commerce platforms), while also extending to traditionally non-digital industries undergoing digitization, such as finance, agriculture, or health. The diffusion dynamics and spillovers described previously therefore operate both within core digital sectors and across the wider economy.²

According to UNCTAD (2019), the digital economy can be structured along three hierarchical and interdependent layers³:

1. **A core ICT sector**, comprising the production of foundational and enabling digital technologies, infrastructure, and services such as semiconductors, ICT hardware, software, telecommunications, and cloud computing;
2. **A wider digitized economy**, which includes all activities relying on or are significantly enabled by digital inputs (such as data, digital services, and infrastructure), including e-commerce, digital platforms, fintech, online content, creative industries, or digitally delivered professional services; and
3. **A digitalized economy**, covering sectors —such as finance, agriculture, manufacturing, health, education, and logistics – that are not inherently digital but are undergoing digital transformation through the integration of digital technologies in their operations.

While the ICT sector is well defined in international classifications, the frontiers of the digitized and digitalized economy are blurry, because of heterogenous diffusion and intensity in DTs use. This blurriness makes assessments of the relative importance of the digitized and digitalized economy evolution across time and space hard to undertake.

Focusing on the core ICT sector, accurate and up-to-date data on its size is lacking, even in high-income countries (OECD, 2024).⁴ However, nowcasts based on machine learning

² The digital economy cuts across multiple industries as defined in the International Standard Industrial Classification (ISIC Rev.4). Core ICT industries include Manufacturing of ICT goods (e.g., computers, communication equipment – ISIC 26, 27), Telecommunications (ISIC 61), Computer programming and consultancy (ISIC 62), Information services and web hosting (ISIC 63), and selected digital platform activities and online services.

³ In the forthcoming ISIC Rev.5 classification, digital industries span a wide array of sectors involved in the production of digital goods, the provision of digital services, and the intermediation of digital transactions (OECD, 2025). These include the manufacture of electronic components, computers, and communication equipment (ISIC 26); telecommunications services, encompassing wired, wireless, and satellite communication (ISIC 61); computer programming, consultancy, and related IT services (62); data processing, web hosting, and other information services (63); publishing activities, including software and digital content (58); advertising services, including digital advertising (73); rental and repair of ICT equipment (77 and 95); and selected creative, professional, and technical activities enabled by digital platforms (74 and 90). In addition, parts of administrative support services (82), education (85), and entertainment and gambling (92) are included where activities are digitally delivered or mediated. This classification reflects the cross-cutting nature of the digital economy and its integration into both ICT-intensive sectors and digitally transforming traditional industries.

⁴ To my knowledge, the most recent data on ICT value added and employment in OECD countries goes back to 2011, representing 6% of total value added, and 3.7% of business sector employment at that time.

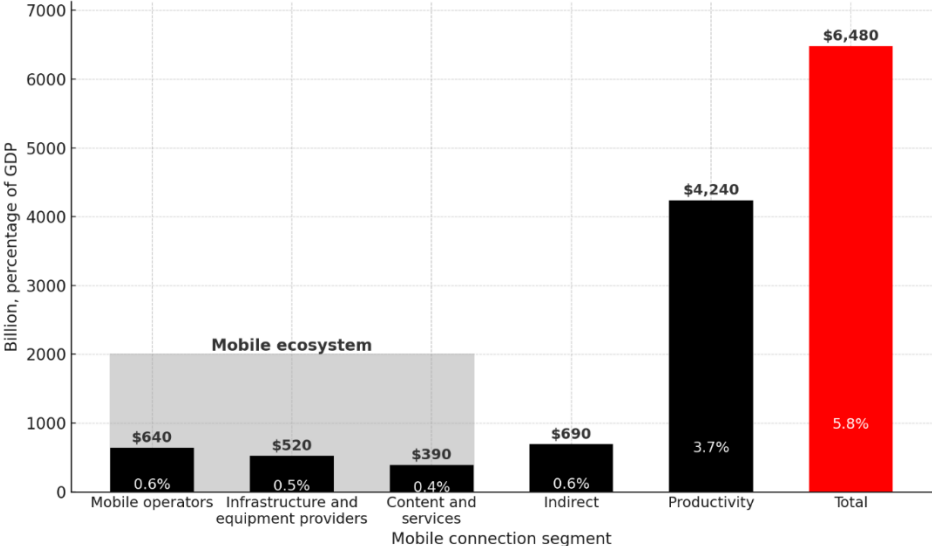
techniques and big data indicate that the ICT sector in OECD countries has experienced consistent growth across OECD countries over the past decade, although at uneven rates. In 2023, the sector recorded strong performance across the board, with an average growth rate of 7.6%. Ten countries—including Austria, Belgium, Canada, Germany, and the United States—exceeded 9% growth, and in Belgium and the United Kingdom, the ICT sector expanded by more than 11%. This surge is partly attributed to sustained demand for ICT products and services in the post-COVID context.

In low- and lower-middle-income countries, the size or growth of the ICT sector are hardly measurable. However, according to the GSM Association (2024, 2025), mobile technologies and services would have contributed to 7% of African GDP in 2023, to 5.8% of the global GDP in 2024, and are expected to contribute to 8.4% in 2030 (GSMA, 2024, 2025), principally through productivity improvements (Figure 1.1). This rising growth contribution of the mobile industry is proper to developing economies, as suggested by GSMA data which indicates that the *average revenue per user* is expected to grow at a compound annual growth rate of 3% in low- and middle-income countries between 2024 and 2030, against 1% in high-income countries (GSMA, 2025).

Despite this progress, the development of the ICT sector in low-income settings faces persistent challenges: limited broadband penetration (ITU, 2023), human capital shortages (World Bank, 2021), low access to finance (GSMA, 2022; Global Findex, 2025), and weak regulatory environments (UNCTAD, 2022). These bottlenecks constrain the sector’s growth potential and its capacity to generate spillovers in other parts of the economy.

Nevertheless, where enabling conditions are met, the ICT sector can contribute to job creation, productivity gains, and export diversification. It can also accelerate the broader diffusion of digital technologies and services across sectors, from agriculture and education to health and public administration.

FIG 1.1. ECONOMIC CONTRIBUTION TO THE GLOBAL GDP OF MOBILE TECHNOLOGIES AND SERVICES, 2024.



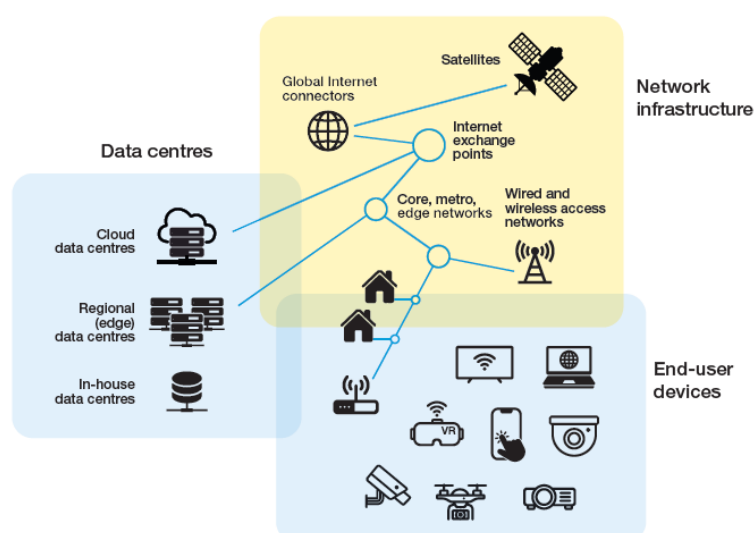
Source: drawn from GSMA (2025).

2. Diffusion of digital technologies and digital divides

At the core of digital technology diffusion lies the infrastructure of the ICT sector, organized around three interdependent layers that mirror the structure of the **Internet value chain**: network infrastructure, data centers, and end-user devices (Figure 2.1). Network infrastructure comprises the physical and logical systems that enable digital connectivity. It includes the first-mile infrastructure—mainly submarine cables, which carry around 99% of global Internet traffic (Telegeography, 2025), and, to a lesser extent, satellite links—followed by Internet Exchange Points (IXPs) that facilitate efficient routing of data at the international, regional, or national levels. Further along the chain, middle- and last-mile access networks (both wired and wireless) transmit data to end users. The second layer, data centers, serves as the backbone for storing, processing, and delivering digital content. The final layer includes the end-user devices through which individuals access the Internet and digital services, such as feature phones, smartphones, computers, IoT-enabled sensors, and drones.

The Internet value chain describes this sequence of interconnected segments through which digital content and services are created, transmitted, and consumed (Schumann & Kende, 2013). It begins with international connectivity (submarine cables and satellites⁵), continues through national backbones and metropolitan networks, and culminates in last-mile access. Along this chain, critical infrastructure nodes—such as data centers, IXPs, and user terminals—ensure the system’s functionality and efficiency. Each segment adds value and depends on coordinated investment and regulation across public and private stakeholders. Weaknesses or bottlenecks in any segment—whether limited submarine cable landing points, underdeveloped IXPs, constrained data center capacity, or unreliable last-mile networks—can degrade service quality, increase costs, and significantly impede the diffusion of digital technologies, especially in low-connectivity environments.

FIG. 2.1. INFRASTRUCTURES OF THE ICT SECTOR AND THE INTERNET VALUE CHAIN



Source: drawn from UNCTAD (2024), based on Pohl and Hinterholzer (2023).

⁵ Though satellites also represent a strong alternative to last-mile links such as cell towers and fiber cables in remote areas.

Digital technology diffusion is hindered by disruptions or weak links between the three layers of digital infrastructure. These disruptions give rise to what is commonly referred to as the **digital divide**—the uneven access to and use of digital technologies across regions, populations, and socio-economic groups. The **infrastructure gap**, a central component of this divide, stems from physical limitations such as uneven deployment of broadband networks, energy infrastructure, insufficient carrying or data center capacity, or limited access to appropriate end-user devices. However, digital exclusion is not solely a matter of infrastructure. The **usage gap** also plays a critical role: it is shaped by limited digital literacy and skills—often linked to broader educational deficits—as well as by restrictive social norms, particularly those that disadvantage women and marginalized communities. Financial constraints remain a persistent obstacle, with affordability cited as the most common reason for not owning smart phones or accessing mobile Internet services (Global Findex, 2025). A third and less discussed dimension is the **technology gap**, referring to disparities in the quality and capacity of the digital tools available to users. This gap can affect how effectively individuals, firms, and administrations leverage digital technologies into daily life and economic activity, ultimately shaping who benefits from digital transformation and to what extent. For example, a small firm that relies solely on mobile broadband in its daily operations is constrained in adopting data-intensive tools—such as cloud services, digital payments, or AI-based analytics—and cannot do so as effectively as a competitor equipped with computers and fixed-line broadband access.

2.1. The infrastructure gap

2.1.1. The international infrastructure gap

Recent studies highlight the critical role of backbone telecommunications infrastructure—particularly submarine cable (SMC) deployment and its corollary, international bandwidth capacity—in facilitating cross-border data flows and ultimately the diffusion of digital technologies (Hjort & Poulsen, 2019; Cariolle, 2021; Simione & Li, 2021). However, access to global bandwidth capacity remains uneven across regions, as illustrated by figure 2.2. Over the past decade it has expanded significantly in Europe, Asia-Pacific, and the Americas; while Africa, Arab States, and CIS countries continue to lag behind, despite recent catchup.⁶ This regional disparity indicates persistent global digital divides.

Figure 2.3 further illustrates how uneven infrastructure deployment affects bandwidth capacity, showing a neat positive correlation between international bandwidth capacity and foundational infrastructures, such as submarine cables, data centers, IXPs, and electricity access. These correlations underline the critical importance of comprehensive infrastructure ecosystems: reliable power grids and terrestrial networks are necessary complements to international connections, without which bandwidth remains underutilized.

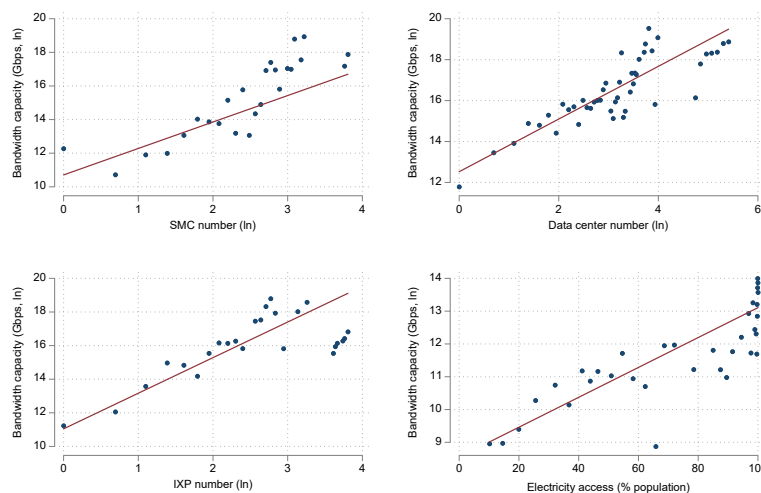
⁶ SMC maps in Appendix A.1 illustrate this gradual and uneven rollout.

FIG.2.2. INTERNATIONAL BANDWIDTH CAPACITY, REGIONAL TRENDS, 2008-2021.



Source: International Telecommunications Union. ITU regional classification.

FIG. 2.3. BANDWIDTH CAPACITY AND BACKBONE INFRASTRUCTURES, WORLDWIDE EVIDENCE, BINNED SCATTER PLOTS, 2008-2021.

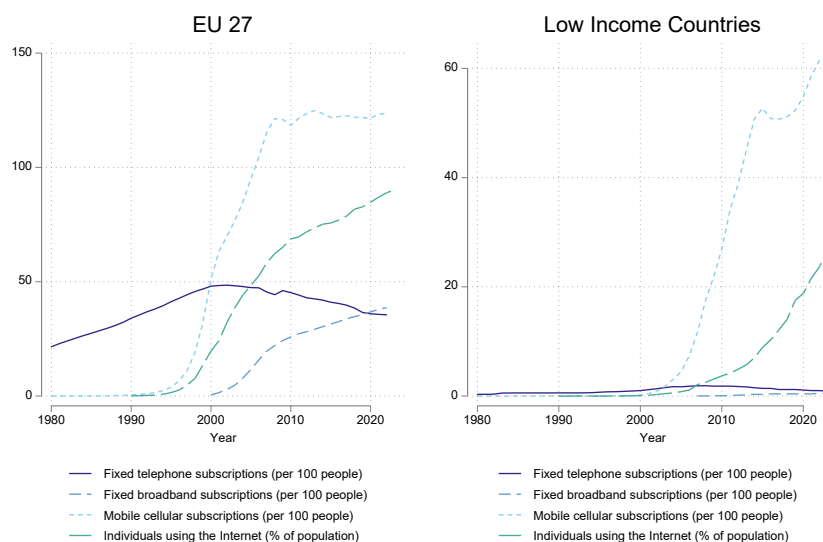


Source: author. Raw data from International Telecommunications Union and World Development Indicators, Telegeography, Packet Clearing House and Peering DB databases. “SMC” stands for submarine cable, “IXP” stands for internet exchange point, “Gbps” stands for Giga bit per second.

2.1.2. The terrestrial infrastructure gap

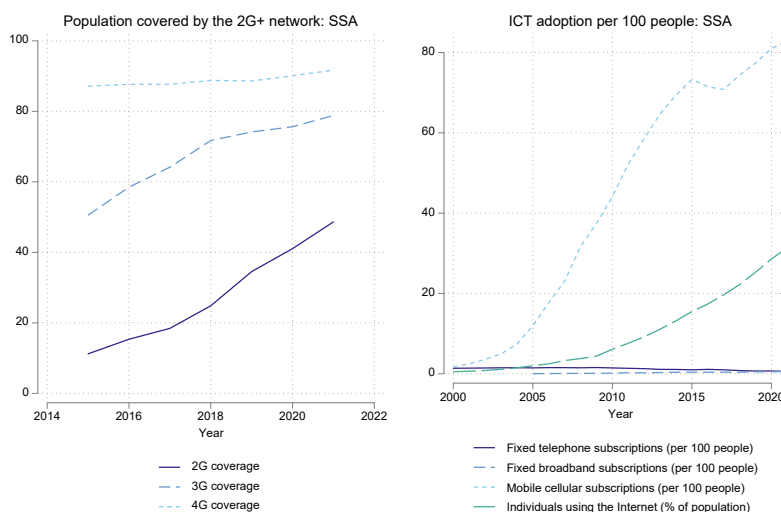
Once SMCs are laid, access to telecommunications and Internet primarily relies on the terrestrial network. In lower-income countries, this network is mainly the mobile (broadband) infrastructure network, with cell towers the principal "last mile" infrastructure (Figure 2.4, right-hand side graph). In this regard, even in poorer regions like sub-Saharan Africa (SSA), mobile Internet coverage (3G, 4G) has steadily expanded, reaching 90% of the population and making mobile phones the main vehicle for Internet access (Figure 2.5). In contrast, higher-income countries extensively rely on fixed broadband networks, including when reaching the last mile, often relegating mobile infrastructure to a supplementary role (Figure 2.4, left-hand side graph). This dual deployment pattern profoundly influences Internet access devices and the types of digital services accessible to users.

FIG. 2.4. ACCESS TO LAST-MILE INFRASTRUCTURES AND INTERNET ADOPTION, EUROPEAN UNION VS LICs.



Data source: International Telecommunication Union (ITU) – with minor processing by ourworldindata.org. Note: Landline Internet subscriptions are defined as a fixed access to the public Internet with a download speed of at least 256kbit/s. Internet users are people who have accessed the Internet from any location in the last three months.

FIG. 2.5. ACCESS TO LAST-MILE INFRASTRUCTURES AND INTERNET ADOPTION, AFRICA.



Data source: International Telecommunication Union (ITU) – with minor processing by ourworldindata.org. Note: Landline Internet subscriptions are defined as a fixed access to the public Internet with a download speed of at least 256kbit/s. Internet users are people who have accessed the Internet from any location in the last three months.

2.1.3. Infrastructure vulnerabilities

In parallel to expanding broadband (BB) Internet access and stimulating digital ecosystems, infrastructure rollout also creates exposure to systemic risks when network redundancy is limited to a small number of cable routes. Failures can occur at multiple layers of the Internet value chain, but SMC cut or fault is probably the most harmful digital hazard: they were the second most common cause—after government interventions—of Internet shutdowns in

2024.⁷ The resulting economic costs are substantial: estimates from Brookings (2016) put the global GDP losses from Internet disruptions at least at US\$2.4 billion over a single year, with individual country losses reaching US\$968 million in India, US\$465 million in Saudi Arabia, and US\$320 million in Morocco. A Deloitte (2022) study similarly found that major connectivity disruptions can wipe out hundreds of millions of dollars in economic output in a matter of days, underscoring the high stakes for countries heavily reliant on a limited set of international cable routes.

Despite the massive laying of SMC by the end of the 2010s, the growing reliance on a yet insufficient number of undersea connections has also made the region vulnerable to disruption in its SMC network. Over the past decades, multiple cases of cable disruptions have exposed the fragility of SSA's international connectivity. In July 2009, a break in the SAT-3 cable linking Europe to South Africa caused major service interruptions in Benin, Togo, Niger, and Nigeria. A similar incident occurred in May 2011 when a ship's anchor severed the same cable, disrupting Internet access for up to two weeks in several West African countries. In June 2017, the MainOne cable failed 3,000 km off the Portuguese coast, again affecting service across the region. That same month, Somalia lost Internet connectivity for over three weeks after its only SMC was cut by a container ship anchor.

The vulnerability of Africa's international connectivity infrastructure was starkly illustrated in March 2024, when simultaneous submarine cable failures disrupted Internet access across both West and East Africa. In the Atlantic Ocean, damage to major cables—including ACE, MainOne, SAT-3, and WACS—severely affected services in countries such as Ghana, Nigeria, Côte d'Ivoire, and Senegal, interrupting banking operations, government services, and digital communications for several days. At the same time, in the Red Sea, outages to the SEACOM and EASSy cables disrupted connectivity in Kenya, Tanzania, Rwanda, and Uganda, with users reporting degraded service and slow speeds for nearly two weeks.

SMC damages are mainly caused by maritime activities—particularly anchoring and fishing nets⁸—and, to a lesser extent, by sabotage or natural hazards, such as earthquakes or typhoons. These disruptions paralyzed key sectors such as digital payments and logistics, and exposed the heavy dependence of LICs on a handful of international cable routes with limited redundancy. The continental scale of the impact of some fault events the urgent need for more resilient digital infrastructure, including diversified routing, regional interconnection, and terrestrial backup systems.

Country's exposure to Internet shutdowns caused by SMC failures has been growing over the years, disproportionately affecting developing regions. In 2024, SMC outages were the second cause of Internet disruptions worldwide, after government interventions, and were mostly hitting SSA.⁹ The data shown in Figure 2.6 illustrate the region's disproportionate experience of Internet disruptions caused by SMC damages over the past two decades. Between 2008 and 2020, African countries experienced more than a thousand cumulative days of SMC-related repairs, reflecting a recurrent and systemic risk. Beyond the immediate economic costs, such infrastructure failures have lasting adverse effects on the diffusion of digital technologies,

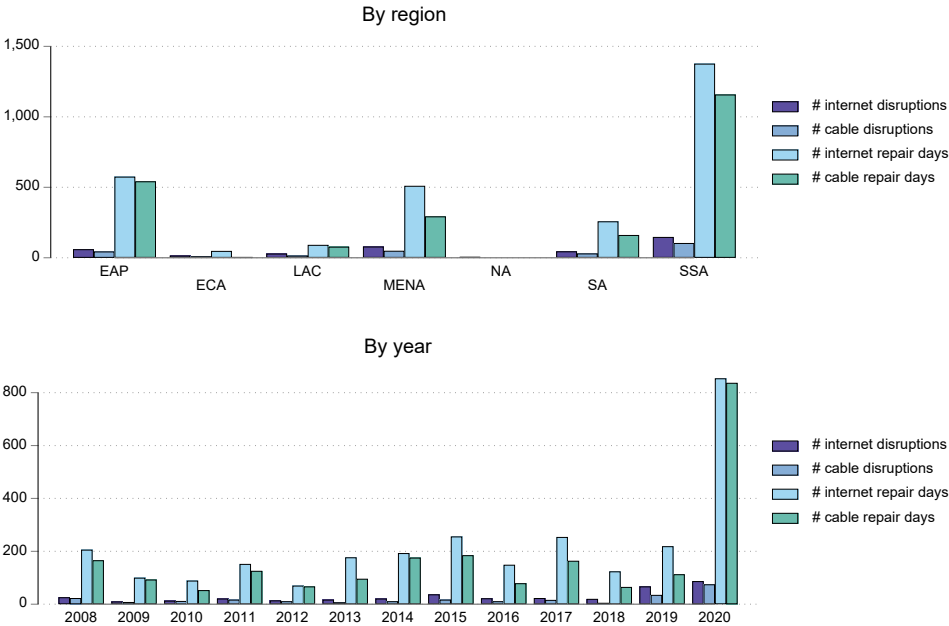
⁷ <https://radar.cloudflare.com/year-in-review/2024#internet-outages>

⁸ <https://www.iscpc.org/publications/icpc-viewpoints/damage-to-submarine-cables-from-dragged-anchors/>

⁹ 38 over 40 internet disruptions caused by SMC cuts were located in SSA, according to Cloudflare data, accessible here: <https://radar.cloudflare.com/year-in-review/2024#internet-outages>. Appendixes A.3 and A.4 provide maps of Internet outages, all causes considered and SMC-related, in 2024.

slowing the pace of digitalization in affected countries. Cariolle (2018) finds that a single SMC outage can lead to a 2-percentage-point drop in Internet penetration and a reduction of 10 mobile subscriptions per 100 inhabitants within two years of the incident. Further evidence discussed later in this chapter also shows that these disruptions tend to strongly depress trade flows.

FIGURE 2.6. REGIONAL AND HISTORIC DISTRIBUTION OF INTERNET SHUTDOWNS, SMC DISRUPTIONS, AND ASSOCIATED REPAIR DAYS, BY REGION AND YEAR.



Data source: Author's data and calculation. Raw data drawn from the Subtel forum <http://subtelforum.com/category/cable-faults-maintenance/>, Akamai's reports on the "State of Internet Connectivity", and completed by manual Internet searches. The dataset is not exhaustive of all cable faults but records documented disruptions that effectively impaired Internet connectivity.

2.2. The usage gap

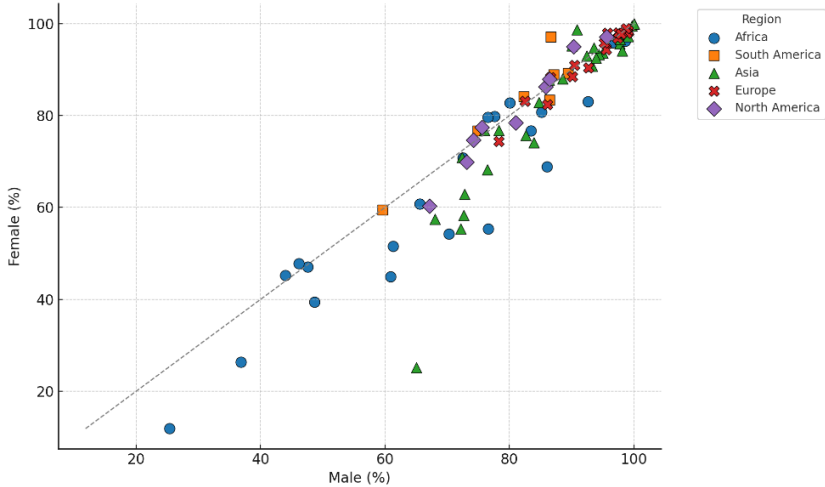
These infrastructural disparities and vulnerabilities are further reinforced by substantial usage gaps, reflecting barriers beyond mere physical access, and shaping the population's digital absorptive capacity. Several determinants underpin these gaps: affordability constraints that limit individuals' capacity to acquire digital devices and connectivity services; education disparities that hinder digital literacy and practical technology skills; gender inequalities that disproportionately affect access to technologies and related resources; and broader socio-demographic factors such as language fragmentation that exacerbate disparities in DT adoption (World Bank, 2021; Aker & Cariolle, 2021; Global Findex, 2025). Collectively, these factors are particularly pronounced in the diffusion and adoption of Internet-based technologies.

In low-income regions, Internet adoption has largely been driven by mobile technologies, due to relatively high feature phone penetration but lower levels of computer and fixed broadband adoption. However, in many low-income contexts, Internet use is impeded by the large cost of smart phones and Internet subscriptions, as well as the digital and literacy skills necessary to navigate the web. Consequently, digital technology diffusion and upscaled digital innovation remains constrained to basic digital services accessed via mobile devices (Aker & Cariolle, 2023). For instance, widely adopted services such as mobile money rely primarily on feature

phones rather than advanced Internet-based technologies. By contrast, developed and emerging regions witness combined adoption of fixed and mobile broadband, fostering widespread use of sophisticated digital technologies such as artificial intelligence (AI), cloud computing, and the Internet of Things (IoT).

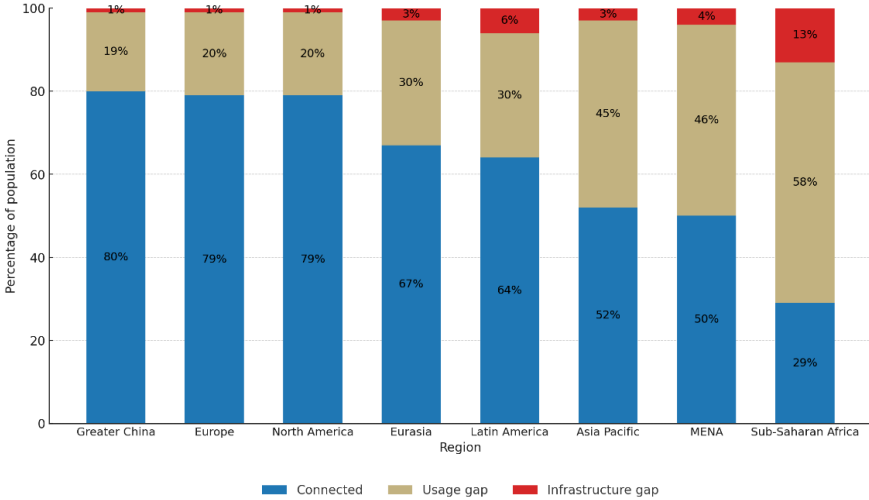
These infrastructural and usage gaps further intersect with demographic inequalities, particularly gender disparities. Figure 2.7 illustrates persistent gender gaps in simple mobile phone ownership, notably in many African and Asian countries. The contribution of the infrastructure and usage gaps to Internet diffusion is further illustrated in Figure 2.8, which breaks down the population between uncovered, covered but not using, and users (connected) of mobile Internet. It appears that the usage gap is the most important obstacle to connectivity, especially in Sub-Saharan and North African countries.

FIG. 2.7. SHARE OF PEOPLE WHO OWN A MOBILE PHONE, BY SEX, 2023



Source: International Telecommunication Union (ITU) – with minor processing by ourworldindata.org. Note: Data reported reflects the share of male or female Individuals with a mobile phone with at least one SIM card that has been used in the last three months.

FIG. 2.8. MOBILE INTERNET DIVIDE BREAKDOWN BY REGION, 2024.

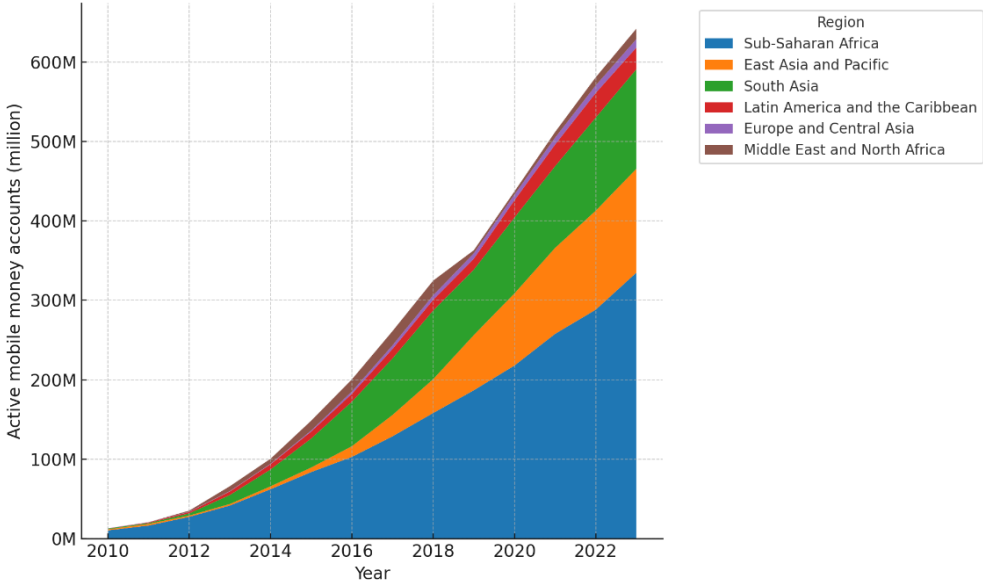


Source: adapted from GSMA (2025).

2.3. The technology gap and heterogenous digitalization pathways

Therefore, gaps in infrastructure deployment and digital usage generate digital divides globally and locally. This uneven access to digital infrastructure and capabilities also leads to a significant technological divide, with major implications for the types of digital technologies that populations can adopt and leverage. In many low-income countries, particularly in Africa, scaling Internet-based advanced digital technologies remains constrained due to limited Internet diffusion and sparse fixed broadband infrastructure coverage. Consequently, widespread digital innovations have typically emerged on mobile platforms primarily through feature phones, such as MoMo services (e.g., M-Pesa in Kenya). MoMo has indeed become a scalable and inclusive technology precisely because it is accessible through basic mobile phones and USSD systems, requiring neither smartphones nor Internet connectivity (Aker & Cariolle, 2023). Figure 2.9 underscores the uptake of MoMo in low-income settings, particularly in Sub-Saharan Africa, where it has significantly contributed to financial inclusion.

FIG. 2.9. HISTORICAL AND REGIONAL DIFFUSION OF MOMO TECHNOLOGY.

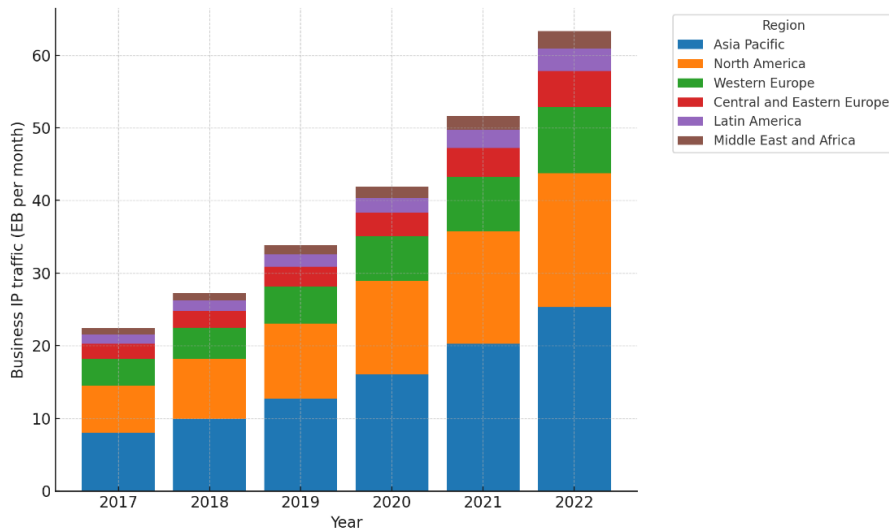


Source: GSM Association (2024) – with minor processing by ourworldindata.org.

Despite some examples of upscaled digital innovations in LICs, the overall scope for advanced digital technology adoption, such as AI and cloud computing, remains significantly concentrated in developed and emerging regions, such as North America, Western Europe, and Asia. In fact, high-income countries benefit from large-scale joint deployment of fixed and mobile broadband infrastructure that enables more advanced and data-intensive technologies, such as cloud computing, AI, big data analytics, and IoT technologies. These technologies require stable, high-capacity connections, large-scale server infrastructures, and digital platforms capable of handling large volumes of data.

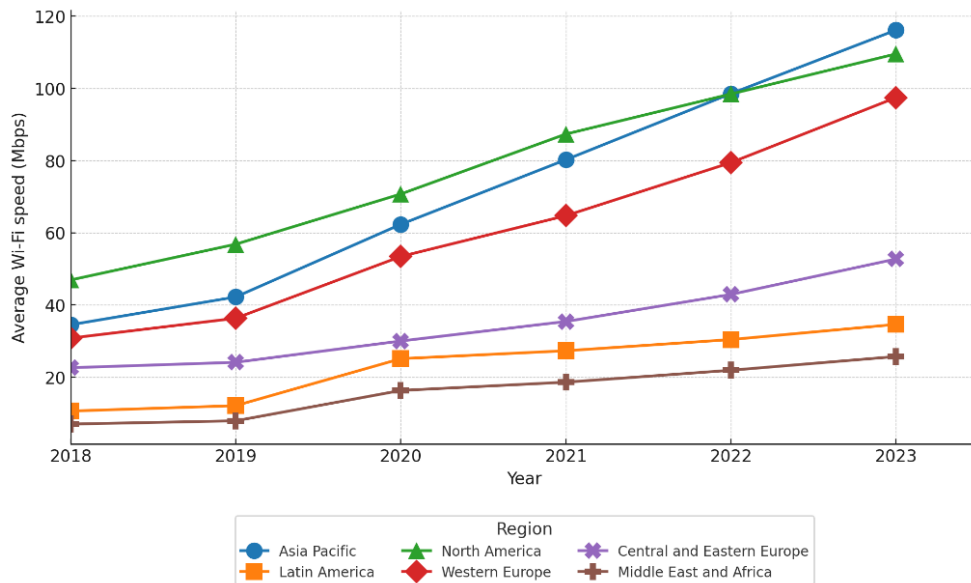
As shown in Figures 2.10 and 2.11, business IP traffic is overwhelmingly concentrated in North America, Asia, and Western Europe, and Wifi speed markedly higher in these same regions, reflecting their digital infrastructure advantage and leadership in adopting data-intensive digital services and innovations.

FIG. 2.10. HISTORICAL AND REGIONAL TRENDS AND FORECASTS OF BUSINESS IP TRAFFIC, 2017-2022.



Source: Adapted from Cisco Visual Network Index 2017-2022 (2019). Business IP traffic is the business traffic that is transported over IP but remains within the corporate WAN. The enterprise forecast is based on the number of network-connected computers worldwide.

FIG. 2.11. HISTORICAL AND REGIONAL TRENDS AND FORECASTS OF WI-FI SPEED, 2018-2023

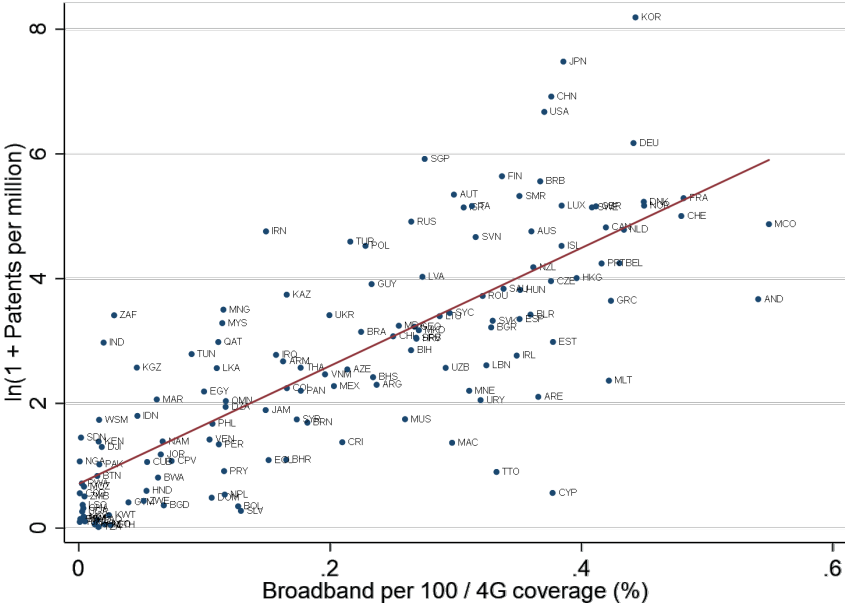


Source: Adapted from Cisco Annual Internet Report 2018-2023 (2020). Wi-Fi speed is informative on both the quality of the broadband connection and the Wi-Fi standard in CPE devices.

The result is a dual digitalization landscape globally: while some countries fully leverage sophisticated, high-value digital innovations, others rely predominantly on simpler, mobile-based technologies. Importantly, this technological divide is shaped not only by infrastructure availability, but also by the depth of the usage gap. Limited digital literacy, high costs of devices and connectivity, and broader socio-economic barriers prevent many individuals from fully leveraging existing digital networks. Even when infrastructure is in place, disparities in skills and affordability mean that uptake of more complex technologies remains restricted, thereby reinforcing technological inequality.

Figure 2.12 highlights the unequal distribution of digital dividends—specifically, innovation outputs such as patent creation—across countries with varying digital infrastructure. It plots a composite metric of fixed broadband subscriptions relative to 4G coverage, reflecting the number of fixed BB subscriptions per 4G-covered individual, revealing that countries with joint access to fixed and mobile broadband networks tend to exhibit higher patenting activity. This graphical evidence highlights the role of high-speed Internet technologies as potential conduits for sophisticated, innovation-driven digital uses, beyond the basic functionality typically supported by mobile networks. Therefore, while mobile Internet access is conducive to digital inclusion, especially when the fixed BB infrastructure is missing, fixed broadband appears to be a stronger driver of high-end digital capabilities and innovation outcomes.

FIG. 2.12. JOINT ACCESS TO FIXED AND MOBILE BROADBAND TECHNOLOGIES AND PATENT CREATION.



Sources: World Intellectual Property Organization (WIPO), via World Bank (2025) – with minor processing by ourworldindata.org; United Nations Population Division, Eurostat, national statistical offices, and United Nations Statistics Division, via World Bank (2025). Note: Fixed BB penetration is measured by the number of fixed BB Internet subscription per 100 people. Patent creation is the annual number of patent applications filled per million people.

3. Laying the first-mile: submarine cables rollout and Internet accessibility

International telecommunications infrastructures are at the core of international exchanges and cooperation. The International Telecommunications Union (ITU) creation in 1865, the oldest United Nations’ agency, is a reflection their central and historical contribution to the globalization process. When the first telegraphic cables were laid in the 18th and 19th centuries between the Americas, Europe and Asia to enable long-distance transmission of messages across continents, they were paving the way to modern fiber-optic SMC network architecture. As of today, high-capacity SMC connections carry more than 99% of international data traffic and provide the physical infrastructure needed to expand Internet access and reduce connectivity costs in the remotest parts of the world (Telegeography, 2025).

Despite being the first-mile infrastructure for international telecommunications and the world Internet backbone, SMCs rarely make news outside of major disruptions—such as the 2024

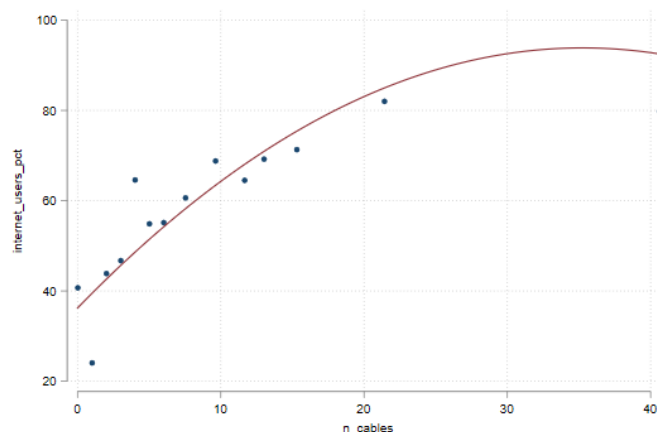
SEACOM outage in the Red Sea, which cut off large parts of East Africa from the global Internet. Yet these underwater fiber-optic cables are essential components of domestic digital economies and primary drivers of digital technologies diffusion, particularly those relying on Internet access, as shown in Figure 3.1 and evidenced in Cariolle (2021).

Recent research shows that the deployment of submarine cable infrastructure is the starting point for digital technology diffusion (Cariolle, 2021; Cariolle et al., 2024). By increasing bandwidth availability, these cables reduce the cost of providing Internet services. This leads to lower broadband prices and therefore higher Internet adoption, especially in low-income countries where affordability remains the most important barrier to digital technology adoption (GSMA, 2025; Global Findex, 2025). In Sub-Saharan Africa, notably, the arrival of submarine cables has been linked to a 3 to 5 percentage point increase in Internet penetration, nearly doubling the regional average before deployment (Cariolle, 2021).

Over the past 30 years, an average of 15 to 20 new cables have been installed annually, gradually connecting more countries to high-speed international networks. Initially concentrated in industrialized economies, this infrastructure is now reaching some of the world’s least connected regions. Submarine cables do not just add capacity—they reduce upstream Internet costs and possibly stimulate competition between telecommunications services providers. These effects make mobile and Internet services more affordable and reliable, laying the groundwork for digital technology diffusion and broader digital development.

This section exposes the main insights from studies conducted by Cariolle et al. (2025) and Cariolle (2021), which respectively highlight the role of international connectivity in explaining Internet retail price drop for a large sample of developed and developing economies, and Internet uptake in SSA countries.

FIG. 3.1. SMC NUMBER AND INTERNET PENETRATION (% POPULATION), WORLDWIDE EVIDENCE, 2008-2021, BINNED SCATTER PLOTS.



Source: Telegeography submarine cable map and World Bank (2025). Sample: 2,369 observations, 173 countries.

3.1. Submarine cable deployment and the cost of Internet access

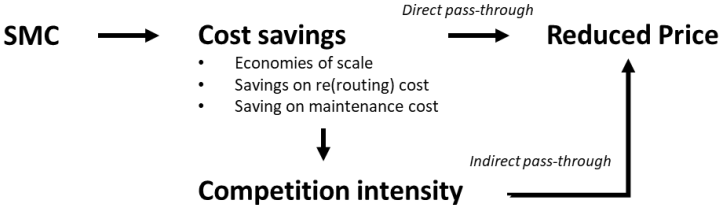
3.1.1. Background

Since affordable Internet access is a key driver of both Internet adoption and broader digital technology diffusion, the cost of delivering bandwidth from landing stations to end users is critical. Understanding these costs requires looking at the upstream infrastructure itself:

submarine cable systems, the principal providers and carriers of bandwidth capacity. These systems require investments of several hundred million dollars and are typically owned by telecom consortia of public and private actors, though increasingly also by major tech firms such as Google, Meta, and Microsoft. By 2023, such content providers accounted for 73% of global bandwidth use.¹⁰

At landing stations, international bandwidth is handed off to domestic Internet service providers (ISPs), directly benefiting connected countries through scale economies, lower transit costs, and improved reliability. Indirectly, when regulatory frameworks ensure open and fair competition in wholesale Internet markets, these cost savings reduce entry barriers, encourage new competitors, and increase the likelihood that reduced costs are passed on to consumers. In contrast, where competition is weak and market power is concentrated in the hands of a few providers, these actors may capture the benefits of scale economies while retaining most of the gains. Submarine cables can therefore reduce broadband prices through two channels: directly, via cost pass-through, and indirectly, by fostering market competition (Fig. 3.2). The magnitude of these effects is therefore reliant on the structure of domestic markets and the strength of regulatory oversight (Wallsten, 2001; 2005).

FIG. 3.2. THE SHORT-TERM IMPACT OF SMCs ON PRICE



Source: drawn from Cariolle et al., (2025).

3.1.2. The price effects of SMC deployment

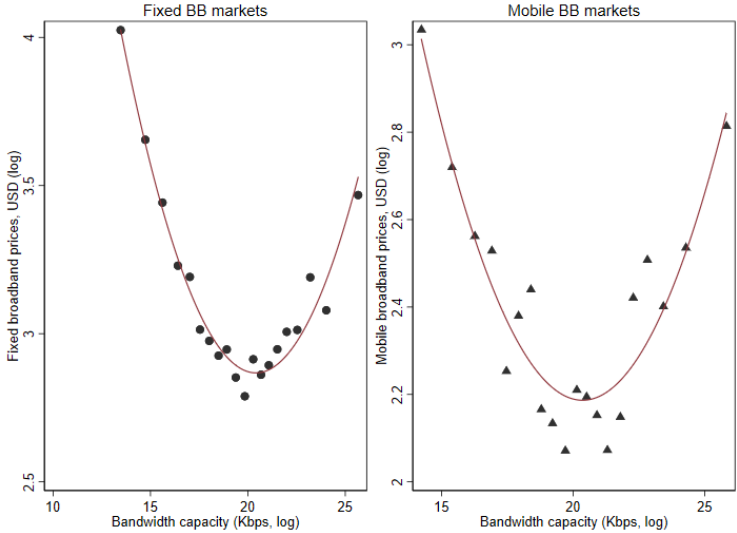
Plotting international bandwidth capacity against fixed and mobile broadband prices, Figure 3.3 reveals a U-shaped relationship, indicating that the price effect of connectivity may be non-linear.¹¹ At lower capacity levels, increases in capacity are associated with falling prices, likely reflecting cost reductions and efficiency gains. However, beyond a certain threshold, prices tend to rise again, which may be linked to higher maintenance and upgrade costs or to reduced competitive pressure in high-capacity markets. This pattern appears more pronounced in fixed broadband than in mobile broadband, possibly due to differences in infrastructure cost structures, investment requirements, and market dynamics.

Two additional correlation plots in Figure 3.4 provide further context, showing that lower competition intensity¹² —reflected by higher market concentration, as measured by the Hirschman-Herfindahl Index (HHI)—is associated with higher broadband prices in both fixed

¹⁰ TeleGeography. (2025). Transport Networks, formerly Global Bandwidth Research Service.
¹¹ Graph drawn from Cariolle et al (2024). The authors use the basket approach to measure and compare Internet prices, relying on ITU-defined baskets, on focusing on two that reflect typical usage today: one for fixed broadband (at least 5 GB/month) and one for mobile broadband (at least 2 GB/month). These baskets have evolved over time to match growing data needs.
¹² Competition intensity is measured using the Hirschman-Herfindahl Index (HHI) of broadband subscribers in retail fixed and mobile markets, based on data from Telegeography (fixed, top 5 providers) and GSMA Intelligence (mobile, all operators). While limited to retail markets, these indicators reflect broader competition along the broadband value chain, including upstream segments.

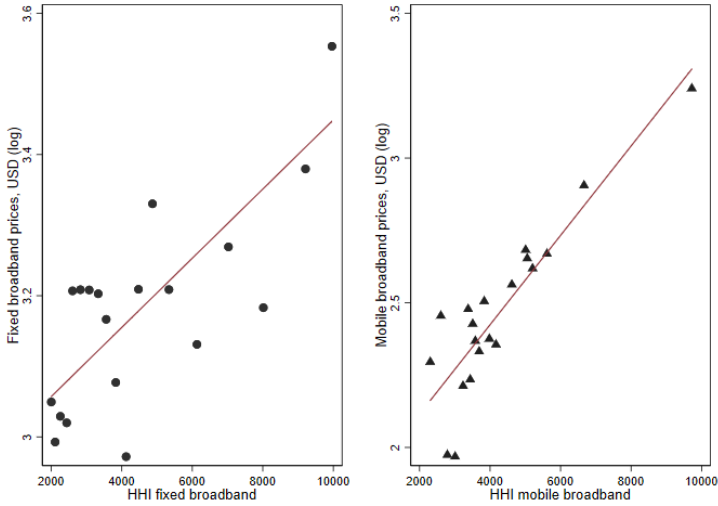
and mobile markets. This descriptive evidence suggests that competitive conditions play a key role in determining how infrastructure improvements translate into lower Internet prices. It also points to the importance of regulatory frameworks that promote and safeguard competition as a central element in ensuring that connectivity gains benefit end-users (Wallsten, 2001, 2005; Cariolle et al., 2025).

FIG. 3.3. INTERNATIONAL CONNECTIVITY AND BROADBAND PRICES, BINNED SCATTER PLOT, 2008-2021



Source: figure drawn from Cariolle et al. (2025). Sample: 150 countries. Period: 2008-2021 (left-side graph, fixed BB prices) or 2012-2021 (right-side graph, mobile BB prices).

FIG. 3.4. MARKET CONCENTRATION AND BROADBAND PRICES, BINNED SCATTER PLOT.



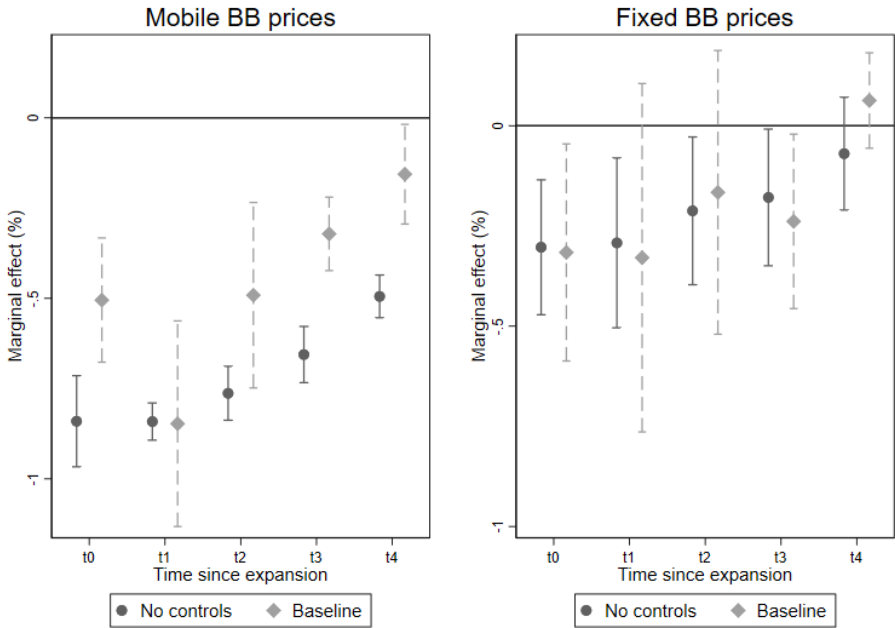
Source: figure drawn from Cariolle et al. (2025). Sample: 150 countries. Period: 2008-2021 (left-side graph, fixed BB prices) or 2012-2021 (right-side graph, mobile BB prices).

Going beyond simple correlation analysis by adopting an instrumental variable approach to estimate the causal effect of SMC capacity on Internet prices, Cariolle et al (2025) show that doubling SMC capacity leads to significant price reductions—up to 50% for mobile broadband

and 32% for fixed broadband (Figure 3.5) – with little regional disparities.¹³ However, these effects decline over time, but more rapidly in fixed broadband markets, where the impact turns insignificant four years after change in bandwidth capacity.

This return of prices to their initial levels may reflect two distinct mechanisms: infrastructure upgrades and market structure. on the one hand, as demand grows, operators invest in improving network quality, which can raise costs. On the other hand, the price drop is shorter-lived possibly due to higher entry barriers and greater market concentration in fixed broadband markets, which limit the pass-through of wholesale cost savings to consumers, and thereby, constraint Internet technology diffusion.

FIG. 3.5. THE IMPACT OF INTERNATIONAL CONNECTIVITY EXPANSION ON BROADBAND PRICE.



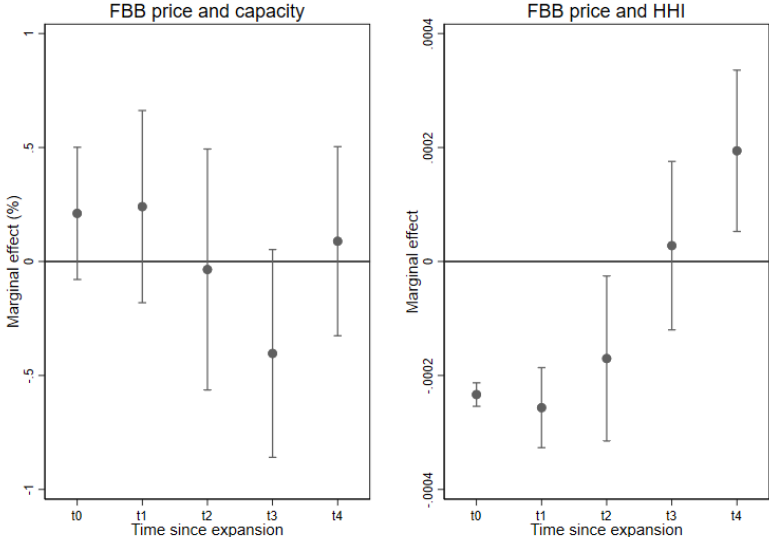
Source: drawn from Cariolle et al. (2025).

Augmenting their empirical framework to study the mediating effect of competition intensity on Internet prices, the authors show that higher market concentration (lower competition) is initially associated with lower broadband prices—a 1000-point increase in the HHI corresponds to a 3% drop in mobile and a 2% drop in fixed broadband prices (Figures 3.6 and 3.7). In fixed broadband markets, market concentration appears to mediate the impact of international bandwidth: once competition intensity is accounted for, the price effect of capacity disappears (Figure 3.6). This suggests that the presence of high infrastructure costs and entry barriers as is usually the case in fixed broadband markets, cost savings from scale may reduce prices in the short term but limit long-term competitive effects. By contrast, mobile BB prices seem to be little affected by competition intensity and rather sensitive to infrastructure capacity (Figure 3.7).

¹³ Using a country-level panel dataset covering 150 countries – for which fixed broadband price data was available over 2008-2021 – and mobile broadband (BB) price data over 2012-2021. Their claim for causal identification relies on an instrumental variable setup exploiting changes in international connectivity due to SMC architecture; i.e. change in the bandwidth capacity of a country’s connected partners. To reduce omitted variable bias, the econometric analysis includes country and year fixed effects, along with key supply- and demand-side controls.

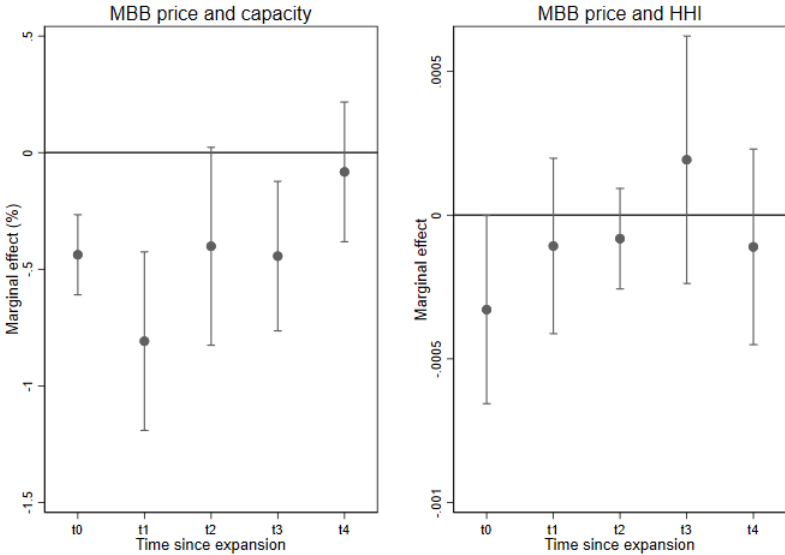
These pricing dynamics have direct implications for the Internet divide, especially the digital technology gap described earlier. In low-income countries, where advanced digital technologies diffusion requires fixed broadband infrastructure access, limited competition could keep prices above affordability thresholds, slowing Internet adoption and preventing the diffusion of data-intensive tools. This reinforces a pattern where digital innovation remains concentrated in high-income regions with dense, affordable fixed broadband networks, while lower income economies rely on less infrastructure-intensive technologies.

FIG.3.6. FIXED BB MARKET PRICES - COMBINED DYNAMIC EFFECTS OF CAPACITY AND COMPETITION.



Source: drawn from Cariolle et al. (2025).

FIG. 3.7. MOBILE BB MARKET PRICES - COMBINED DYNAMIC EFFECTS OF CAPACITY AND COMPETITION.



Source: drawn from Cariolle et al. (2025).

Therefore, SMC laying in developing economies is expected to affect profoundly telecommunication markets and spur digital technologies diffusion, by expanding international bandwidth capacity and lowering the cost of Internet connectivity, provided adequate

regulations are designed and enforced. The next section shows that in Sub-Saharan Africa, this infrastructure expansion has particularly benefitted Internet diffusion in the population.

3.2. Connecting sub-Saharan Africa

Until the late 2000s, Sub-Saharan Africa (SSA) remained largely disconnected from global digital infrastructure (Appendix A.2). Since then, submarine cable deployment has expanded rapidly, with 77 cables that are active or under construction by 2025 (Telegeography, 2025)¹⁴. This rollout has supported a sharp rise in Internet use. Figure 3.8 shows that Internet penetration has grown in parallel with the number of countries connected to the global network. However, despite these advances a strong digital divide persists in the region: by 2024, fewer than 40% of SSA's population was online, with important differences between African countries (ITU, 2025)¹⁵. An empirical study conducted by Cariolle (2021) highlights the role of submarine cables in bridging the region's Internet divide, suggesting that efforts to deploy the Internet infrastructure should be maintained to accelerate DT diffusion.

This study focuses on a specific wave of regional SMCs – the SEACOM and EASSy cables laid in 2009-2010 – which induced a dramatic improvement in the recipient region's connectivity. This wave could have acted as a quasi-experiment for countries hosting these cables for two principal reasons. On the one hand, SEACOM and EASSy were laid across all Eastern and Southern African coastal countries without exception, appearing to follow regional geographic considerations rather than the maturity of national telecom markets or the quality of telecommunications policies. On the other hand, this wave of submarine cables marked the first time a new generation of fiber-optic infrastructure—introduced globally in the mid-2000s—was deployed on the African continent, bringing a dramatic and largely exogenous increase in international telecommunications carrying capacity (Weller & Woodcock, 2013). A visual analysis of the parallel trend assumption in Fig. 3.9 supports that SEACOM/EASSy deployment is a suitable experiment for a Difference-in-Difference (DID) analysis, with treated and non-treated groups displaying confounded pre-treatment trends (1990-2008), in both Internet penetration (Panel A) and bandwidth per user (Panel B), that diverge post-treatment in 2009.¹⁶

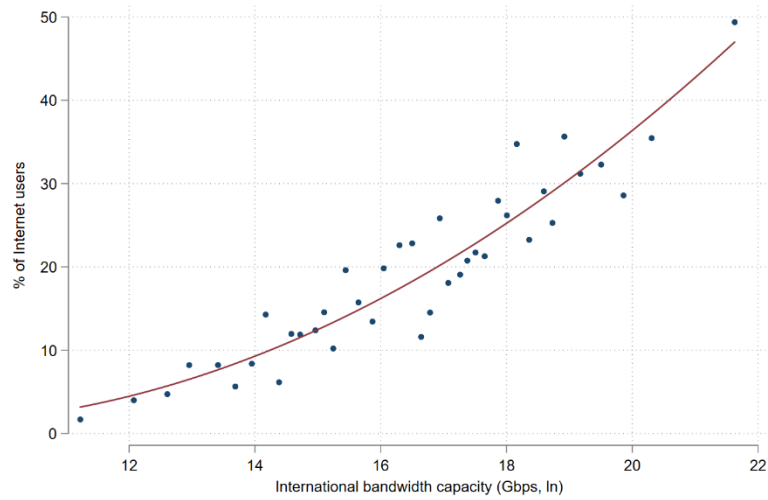
DID estimations reveal that the SEACOM and EASSy cables significantly boosted Internet penetration in recipient countries. In fact, the arrival of these cables resulted in a 3-5 percentage point increase in Internet penetration rates, a substantial improvement given the region's low baseline penetration levels. These findings are robust across various sample restrictions and time periods, highlighting the critical role of SMCs in spurring Internet diffusion in SSA.

¹⁴ <https://blog.telegeography.com/2025-africa-telecommunications-map>

¹⁵ ITU ICT Statistics [portal](#), data retrieved on June 2025.

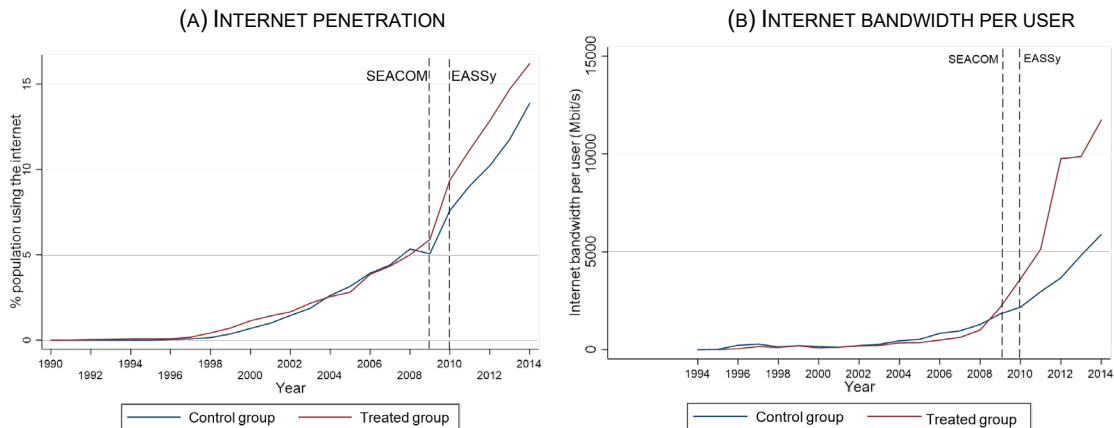
¹⁶ By contrast, SEACOM and EASSy were not found to affect mobile phone penetration. The related graph is not displayed here for the sake of brevity.

FIG. 3.8. INFRASTRUCTURE CAPACITY AND INTERNET PENETRATION IN AFRICA, 2008-2021, BINNED SCATTER PLOT.



Source: International Telecommunications Union and World Development Indicators. Sample: 441 observations, 42 countries.

FIG. 3.9. TREND COMPARISON OF ICT PENETRATION BEFORE AND AFTER SEACOM/EASSY LAYING.



Source: Adapted from Cariolle (2021).

3.3. Discussion and policy implications

Key findings and policy implications, discussed in this subsection, are synthesized in Box 1. The results presented show that improvements in first-mile connectivity have been particularly striking in SSA, and a fortiori in many low and middle-income countries, which experienced expansion of the digital economy, thereby raising the prospects for growth, job creation and improved living conditions (Hjort & Poulsen, 2019; Choi et al., 2019; Simone & Li, 2021).

The study by Cariolle et al. (2025) and Cariolle (2021) offers important policy insights for enhancing the impact of SMC deployment on broadband Internet affordability, and ultimately Internet diffusion, in developing regions. Observed price reductions following SMC laying, and the differing price dynamics between fixed and mobile broadband, highlight the value of continued investment in international connectivity along with tailored regulatory approaches.

Complementary investment in terrestrial infrastructure—such as IXPs, data centers, and last-mile connectivity—is also essential to spur Internet adoption.

Yet, infrastructure and regulatory policies alone are not enough to reduce the digital divide. Addressing the usage gap is equally critical. This requires improving digital absorptive capacity and equipping individuals, firms, and institutions with the skills needed to use digital tools effectively. A comprehensive strategy that combines infrastructure development, market regulation, and digital capability building can enable low-income regions like SSA to fully leverage digital connectivity—to expand trade, enhance livelihoods, support industrialization and diversification, and build greater economic resilience.

The following sections explore the broader economic impacts of narrowing both the infrastructure and usage gaps in developing countries, beginning with the export sector.

| Box 1. Key findings and policy implications | |
|----------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Main messages: | |
| Progress in SSA | Submarine cable (SMC) deployments have sharply improved first-mile connectivity in SSA and other LMICs, supporting digital economy growth and raising prospects for jobs, trade, and living standards. |
| Prices and connectivity | Evidence shows SMC deployment reduces broadband prices, with distinct dynamics for fixed vs mobile broadband, underscoring the need for continued investment in international connectivity. |
| Complementary infrastructure | To turn cheaper international bandwidth into actual Internet use, complementary terrestrial infrastructure (IXPs, data centres, last-mile networks) is crucial. |
| Beyond infrastructure: usage gap | Infrastructure and regulation alone cannot close the digital divide; tackling the usage gap —who can effectively use digital tools—is equally important. |
| Digital absorptive capacity | Building digital skills and absorptive capacity among individuals, firms, and institutions is necessary for meaningful Internet adoption and productive use. |
| Strategic policy mix | A comprehensive approach combining infrastructure investment, smart regulation, and capability building can help regions like SSA fully leverage connectivity for trade, livelihoods, industrialization, diversification, and resilience. |

4. Leveraging the first-mile: international connectivity and insertion in global trade

4.1. Is there a digital divide in global trade?

Digital technologies have the potential to reshape export participation by easing information frictions and lowering trade costs (D’Andrea & Limodio 2023). Exporters are typically early adopters of new technologies in order to stay competitive globally. Yet, not all exporters are able to capture the same benefits from technological upgrading (Bustos 2011), which limits the overall gains from improved connectivity. A comparison between India and Botswana illustrates this uneven landscape. In 2020, with Internet penetration at just 40%, India’s ICT services already represented nearly half of its services exports, and high-tech products 11%

of manufactured exports (World Bank 2025). Botswana, on the other hand, had Internet access for over 80% of its population by 2023 but ICT services and high-tech exports accounted for only 4.7% and 1% of their totals (World Bank 2025). These contrasting cases highlight that exporters' capacity to harness digital technologies depends heavily on national conditions, with SSA in particular facing persistent challenges due to its low digital readiness (NRI, 2024).

The expansion of broadband infrastructure—particularly SMCs—has significantly reduced international communication costs, facilitating cross-border market information friction, technological transfer, partner matching, and access to regulatory and market information (Rauch and Trindade, 2003; Arkolakis, 2010; Allen, 2014; Dickstein & Morales, 2018; Dasgupta & Mondria, 2018; Akerman et al., 2022). These developments can lower trade costs, especially for differentiated goods and services exchange, subject to strong information frictions (Rauch, 1999).¹⁷ However, the relationship between connectivity and trade performance remains complex and context-dependent.

Early studies, emerging in the wake of the 2000s Internet boom, demonstrated that digitalization—especially in the form of improved Internet access—boosted service exports (Freund & Weinhold, 2002, 2004; Choi, 2010; Haltenhof, 2019). While recent research extended these findings to merchandise trade (Herman & Oliver, 2023), the merchandise trade benefits of the international telecommunications infrastructure preceded Internet diffusion. In fact, Fink et al. (2005) showed that declines in international calling prices¹⁸ stimulated merchandise exports by reducing communication barriers. Today, the growing "servicification" of trade—where high value-added services such as R&D, finance, transport and logistics are embedded in goods production and delivery—further amplifies the role of digital infrastructure (Loungani et al., 2017; Baldwin & Freeman, 2022; Stojkoski et al., 2023; Bahar et al., 2024). Exports of primary products and raw materials, once seen as minimally digital, now increasingly rely on such data-intensive services (Park, 2020; Hounghonon & Mthobi, 2025).

This transformation is visible in evidence from the SEACOM and EASSy cable deployments in Eastern and Southern Africa. As shown in Figure 3.10, drawn from Cariolle & Da Piedade (2025), exports of logistics-intensive categories—most notably mineral products (HS2-25) and vegetables (HS2-07)—rose significantly after the cable deployments, whereas other HS2 product categories did not experience a comparable increase. This pattern is consistent with the high logistics-intensity scores of these products in both 2000 and 2014 documented by Park (2020).. While demand-side factors in importing markets may partly explain these trends and the evidence does not assess product upgrading, the results are nonetheless indicative of gains in logistical efficiency and raw export competitiveness associated with improved digital connectivity.

The benefits of connectivity infrastructure and related digital technologies are therefore uneven, with its trade effects varying widely across industries and exporters. Recent studies shed light on these heterogeneous outcomes of digital connectivity, depending on the quality of digital links and exporters digital absorptive capacity. Imbruno et al. (2025) find that bilateral SMC connections increase export participation among firms in high-income countries, but can prompt exit among exporters in developing economies due to limited technological absorptive

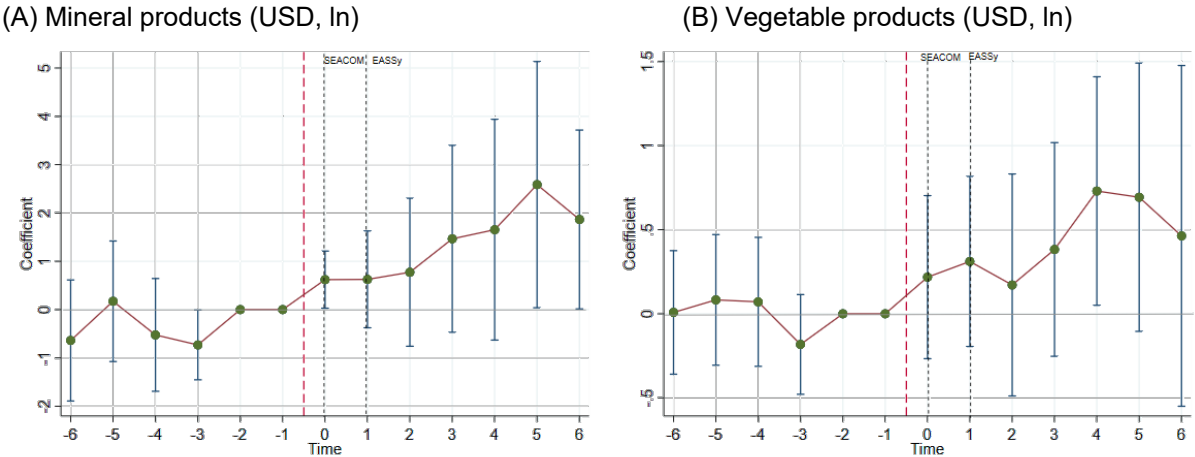
¹⁷ Differentiated goods are products that are distinguished by specific characteristics, such as quality, features, brand, or after-sales service, allowing companies to create a unique identity and attract specific consumer segments. The differentiation of these products gives producers a certain pricing power, as consumers perceive added value linked to these differences. As a result, differentiated goods are associated to higher information search costs for customers.

¹⁸ largely attributable to SMC deployment in the 1990s and early 2000s.

capacity. Cariolle & Da Piedade (2023) introduce the notion of *digital connectedness*, emphasizing not just physical infrastructure density but also the economic importance of connected trade partners. Their results show that direct links to global economic hubs are associated with higher export sophistication in several African countries.

Taken together, this literature highlights the dual nature of digitalization: as a catalyst for export performance and growth, but also as a potential amplifier of global trade disparities. The risk of widening the global trade divide is particularly acute where local conditions limit digital technology absorption and diffusion, and thereby, the capacity of exporters – and ultimately domestic producers – to tap into infrastructure connectivity.

FIGURE 3.10. EXPORTS OF MINERALS AND VEGETABLES PRODUCTS (HS2) AFTER SEACOM/EASSY ARRIVAL IN AFRICA, DYNAMIC EFFECTS.



Source: Cariolle & Da Piedade (2025, forthcoming). Note: Local projection DID estimator from Dube et al. (2023). Controls include a country time trend, GDP (log), population (log), total exports (% GDP) and the lagged first-difference of the dependent variable.

4.2. The trade consequences of heterogenous digital absorptive capacities

Direct submarine cables aim to cut latency and rerouting costs while improving stability. For example, the South Atlantic Cable System (SACS), launched in 2018 to link Angola and Brazil, reduced latency by 21% toward Brazil and 67% in the reverse direction (Fanou et al., 2020), a critical gain for firms relying on fast, stable communication.

In fact, lower latency and greater bandwidth reduce coordination costs for firms operating across borders. Exporters can more effectively manage supplier and customer relationships, logistics, and after-sales services, while also responding more quickly to market shifts and regulatory changes. In sectors like manufacturing and digital services, improved connectivity facilitates tighter supply chain integration and access to new markets (Venturelli & Gabriel, 2021). Beyond operational efficiency, stronger digital links also enhance social and economic connections between countries: digital ties can boost bilateral trade, as shown by Bailey et al. (2021), who find that countries with more online social connections—measured through Facebook friendships—tend to trade more with each other.

However, not all firms are equally positioned to benefit. Leveraging digital infrastructure often requires deep technological and organizational changes (Acemoglu 2002 ; Akerman et al., 2015; Violante 2018). On the one hand, thanks to their more flexible management practices and organizational structure, smaller production units should be more inclined to reap out the

benefits of digital technologies (Sadowski et al., 2002; DeStefano et al., 2018). On the other hand, costs of Internet technologies adoption and information processing are high, so that they might be unaffordable for smaller or less productive firms (Fabiani et al., 2005; Dickstein & Morales, 2018). In global trade, this heterogeneous technological absorption capacity of exporters has been first pinpointed by Bustos (2011) in the context of broad technological change, and recently by Imbruno et al (2025) in the context of digital interconnection and digitalization.¹⁹

Drawing on an extended heterogeneous-firm trade model (Melitz, 2003; Bustos, 2011), Imbruno et al. (2025) find that submarine cable (SMC) connectivity increases firms' participation in international trade but disproportionately benefits the largest firms with the capacity to adapt. In advanced economies, a broader base of firms is able to take advantage of improved connectivity. In developing economies, by contrast, many smaller firms are unable to compete and may exit export markets, exacerbating existing disparities in trade participation.

Their results show that bilateral SMC connections raise the number of exporters by 9.5% when the origin country is developed, but reduce it by 8% when it is developing. Regionally, positive effects are observed in Europe and Central Asia, while declines are recorded in Latin America, SSA, and the MENA region. In developing countries, average export values per firm rise as smaller and less competitive firms exit, whereas in developed countries, the entry of new and smaller exporters tends to reduce the average value per firm.

Interestingly, Imbruno et al. (2025) find that the impact of SMC connections on the number of exporting firms depends on geographical distance. Using both Euclidean and maritime distance measures, they show that in developing countries, the negative effects on exporter numbers are smaller when trading partners are more distant—suggesting that SMCs help reduce distance-related trade frictions in less connected regions. The authors also find that these heterogeneous effects grow with bandwidth capacity and are most pronounced in digitally intensive sectors. However, they are moderated by a country's ability to upgrade its digital skills base—a central component of the usage gap. In developing economies, an increase in the share of highly educated individuals is associated with lower firm exit rates, indicating that investments in human capital can help close the usage gap, mitigate adverse effects, and enhance exporter's capacity to fully benefit from incoming first-mile infrastructures.

4.3. A new distance puzzle? Digital proximity to world markets and export upgrading

Many developing countries have long been marginalized in global trade due to high transaction costs, poor infrastructure, and structural disadvantages such as geographic remoteness and historical legacies. Geographic distance from major markets has been a key factor limiting diversification and increasing vulnerability (Brun et al., 2005; Cariolle et al., 2016; Carrère et al., 2013, 2020). While the “death of distance” hypothesis (Cairncross, 1997) suggested that advances in transport and telecommunications would erase these disadvantages, subsequent studies have challenged this view (Carrère et al., 2013, 2020). The specific role of digitalization

¹⁹ Both studies show that despite being instrumental to a firm's productivity and expansion potential, adoption of complex technologies may be beneficial to adopters while provoking the exit of firms unable to absorb them from foreign or domestic markets.

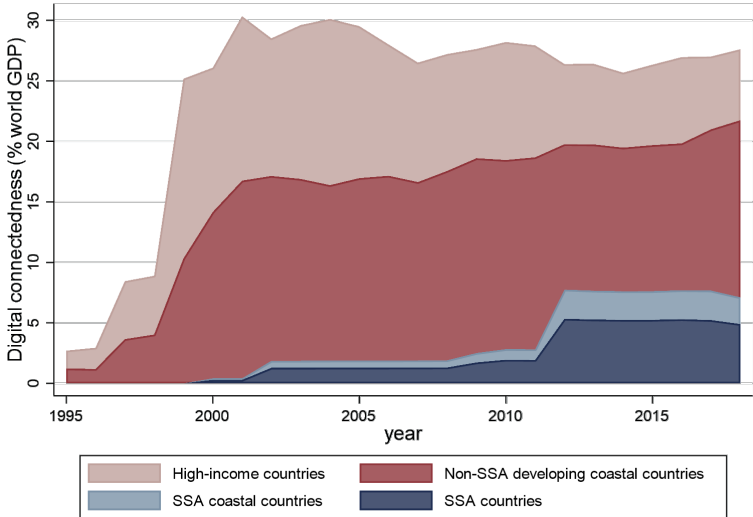
in mitigating the distance effect remains contested (Lendle et al., 2016; Akerman et al., 2022; Imbruno et al., 2025).

Cariolle and Da Piedade (2023) add to this debate by analyzing the contribution of digital connectedness, defined as the share of world GDP directly linked through submarine cables (SMCs), to export sophistication. Higher digital connectedness enhances access to information on trade opportunities, production technologies and regulations by digital technology adopters, fostering export upgrading and diversification. In SSA, a marked increase in digital connectedness occurred in the early 2010s with the deployment of the WACS and ACE cables, which linked the West African coast directly to Europe (Figure 3.11).

Importantly, this study shows that simple measures of connectivity density are insufficient since the quality and direction of connections matter. A digital link between two low-income countries is unlikely to have the same trade impact as a link between a low-income and a high-income country (Imbruno et al., 2025). In particular, connections to major global production and consumption hubs can reduce information frictions and facilitate integration into global trade and stimulate innovations by providing access to advanced technologies, networks of suppliers and customers, distribution channels, and financing opportunities (Allen, 2014; Dasgupta & Mondria, 2018; Akerman et al., 2022).

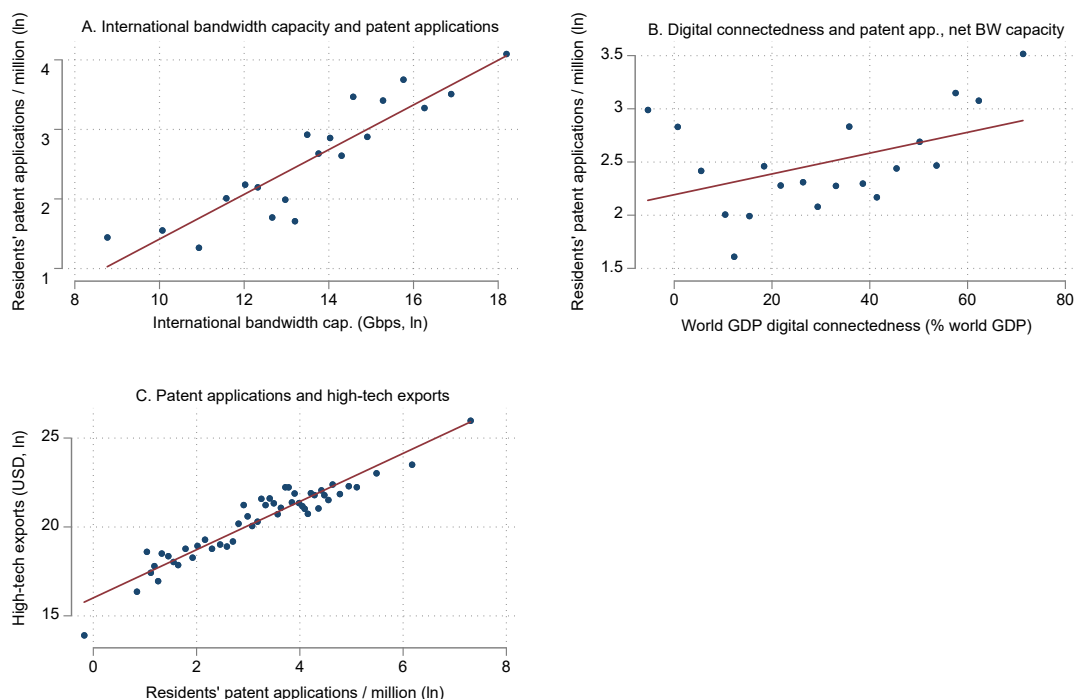
Figure 3.12 illustrates this point. Panel A shows a positive correlation between international bandwidth capacity and residents' patent applications, controlling for GDP per capita, suggesting that connectivity supports innovation beyond income effects. Panel B, using digital connectedness instead of bandwidth capacity, confirms that whom a country is connected to is critical for innovation process: controlling for both GDP per capita and bandwidth capacity, stronger ties to major economic hubs are associated with greater patent activity. Panel C shows that resident patenting is positively associated with high-tech exports.

FIGURE. 3.11. TRENDS IN DIGITAL CONNECTEDNESS (% WORLD GDP), 1995–2017



Note: reproduced from Cariolle & Da Piedade (2023). On the X-axis is reported the average cumulative share of world GDP reached by direct (first-order) SMC connections.

FIG. 3.12. DIGITAL CONNECTEDNESS, PATENTING, AND HIGH-TECH EXPORTS, 2008-2021, BINNED SCATTER PLOT.



Source: International Telecommunications Union and World Development Indicators. Sample: panel A, 1,087 observations, panel B 1,246 observations, and panel C, 1,334 observations. Notes: reported correlation plots in panel A and C are **conditional on controlling for GDP per capita (constant USD, ln)**, while the correlation plot in panel B is **conditional on controlling for both GDP per capita and bandwidth capacity**.

To evaluate the trade upgrading effects of digital connectedness, Cariolle and Da Piedade (2023) use the Economic Complexity Index (ECI) as their primary measure of export sophistication, complemented by alternative indicators such as global value chain participation, product differentiation (Rauch, 1999), and Hausmann et al.'s (2007) export sophistication index. Figure 3.13 shows the average ECI score by region from 1995 to 2017. SSA consistently lags behind other regions in terms of export complexity levels, but from the early 2000s until 2015 it records one of the strongest upward trends. This acceleration coincides with the deployment of major SMC systems serving the region: SAT-3 and WASC connecting Western Africa to Europe in 2002, SEACOM and EASSy connecting Eastern Africa to Asia in 2009–2010, and WACS and ACE reinforcing Africa's telecommunications capacity with Europe in 2012.

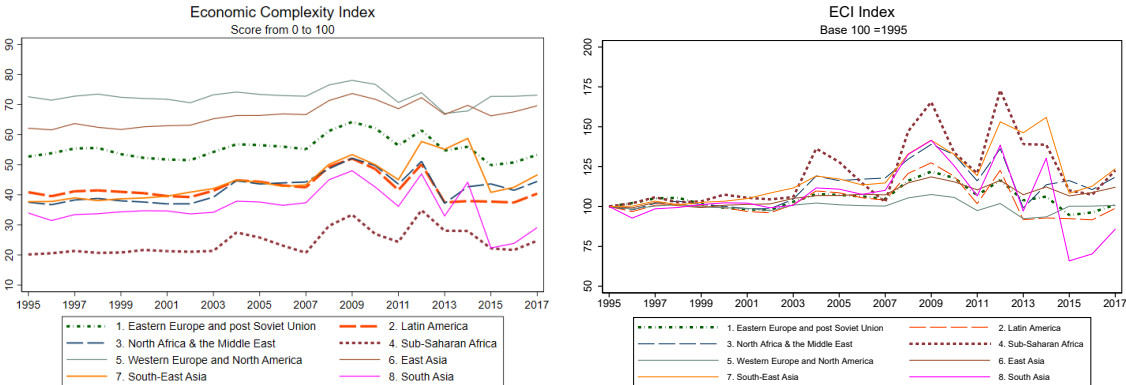
Their analysis finds a positive and significant effect of digital connectedness on export complexity, with especially strong impacts in SSA.²⁰ A notable finding is a *new distance puzzle*: in most regions, the effect of digital connectedness declines with greater distance to major markets – in line with Imbruno et al. (2025)'s findings – except in SSA, where it increases. Using sea-distance data (Bertoli et al., 2016), the authors find that a 3,000 km increase in sea

²⁰ The study employs an instrumental variable (IV) approach to determine the causal impact of digital connectedness on export upgrading. Estimations are conducted on a panel of 60 developing countries, including 23 from SSA, controlling for various factors, including internet penetration, country size, trade openness, and more. The IV setup exploits information on the centrality of the SMC network linking partners to whom a country is connected, and uses the number of distinct second-order SMC connections as an instrumental variable (IV) of a country's digital connectedness.

distance reduces the effect on ECI by 47% in non-SSA countries but increases it by 75% in SSA, suggesting that geographically remote SSA countries, facing high traditional trade barriers, gain disproportionately from improved digital connectivity. Exploring mechanisms, the authors show that maritime transport performance (measured by UNCTAD’s Liner Shipping Connectivity Index) strengthens the impact of digital connectedness, particularly in SSA. They also find that while higher Internet penetration enhances these effects, persistently low rates in SSA limit its role. By contrast, broader primary education coverage significantly amplifies the benefits, indicating that basic human capital plays a critical role in leveraging digital infrastructure for export upgrading.

This evidence on the additional trade benefits of SMC connection quality suggests that infrastructure connectivity is multifaceted and relates directly to the three divides outlined earlier. First, the infrastructure gap is not only about the presence of international bandwidth, but also about whether this capacity connects to strategically important nodes in the global economy. Second, the technology gap concerns the extent to which such connections lead to the adoption of more sophisticated, data-intensive tools, which depends on the quality the linkages and on adopter’s absorptive capacity. Last, the usage gap determines how effectively individuals, firms, and institutions can translate digital connectivity and technology adoption into trade gains, shaped by factors such as digital skills, affordability, and organizational capacity.

FIGURE 3.13. ECI EVOLUTION BY REGION, 1995–2017.



Source: updated from Cariolle & da Piedade (2023).

4.4. From international connectivity to digital vulnerability

While improving international connectivity is a necessary (but not sufficient) step to foster DTs diffusion, digital dividends remain contingent on the stability of underlying infrastructure. As discussed in Section 2.1.3, SMC systems are highly vulnerable to physical damage, technical failures, and natural hazards, with disruptions disproportionately affecting developing regions—particularly SSA, where network redundancy is limited. Such outages not only interrupt the flow of information but can also trigger significant economic losses, disrupt trade logistics, and erode the reliability of digital connections on which exporters and importers, but also domestic firms, strongly depend. In economies where digital technologies become ubiquitous, such disruptions in the first-mile infrastructure access may have serious consequences on economic activities, especially in outward oriented industries.

Theoretically, the main transmission channels are threefold. First, information frictions increase abruptly: firms lose or face delays in accessing real-time information on market conditions,

customers, and suppliers, which is particularly disruptive for digitally intensive trade in goods and services. Second, value chain coordination suffers: global production networks depend on constant digital communication to synchronize activities such as design, quality control, and supply chain management. Cable disruptions can lead to missed deadlines, quality issues, and loss of orders. Third, logistics disorganization emerges, especially for time-sensitive trade flows, as disruptions affect customs clearance, cargo tracking, and shipping coordination. The negative impact is expected to be felt by domestic SMEs that rely on just-in-time processes and lack redundant communication channels, making them less resilient to connectivity shocks.

A quantification of these effects is provided in Figure 3.14, based on the dynamic heterogeneity-robust difference-in-differences estimator (De Chaisemartin et al., 2024), which traces the impact of SMC-related Internet disruptions on various trade components over time.²¹ The sample covers 123 countries and the 2008-2020 period, including 41 HICs, 67 MICs, 15 LICs.²² The treatment variable captures the number of Internet disruptions directly attributable to SMC faults or breaks, events that are plausibly exogenous and mostly related to maritime traffic activity (fishing nets and anchoring).²³ Trade outcomes are measured in 2015 constant US dollars (log-transformed) and cover six categories: total services, merchandize, commercial services, and transport services trade.

Figure 3.14 shows the estimated dynamic trade effects of submarine cable disruptions over a six-year post-treatment horizon. Whether for imports or exports, and across both goods and services, submarine cable disruptions trigger a cumulated decline in trade of roughly 50% within six years. The magnitude of the impact is comparable across categories, and the timing largely overlaps. The contraction of commercial services—including transport services—appears to underpin this synchronicity, linking the downturn in goods and services trade to disruptions in the underlying logistics chain.

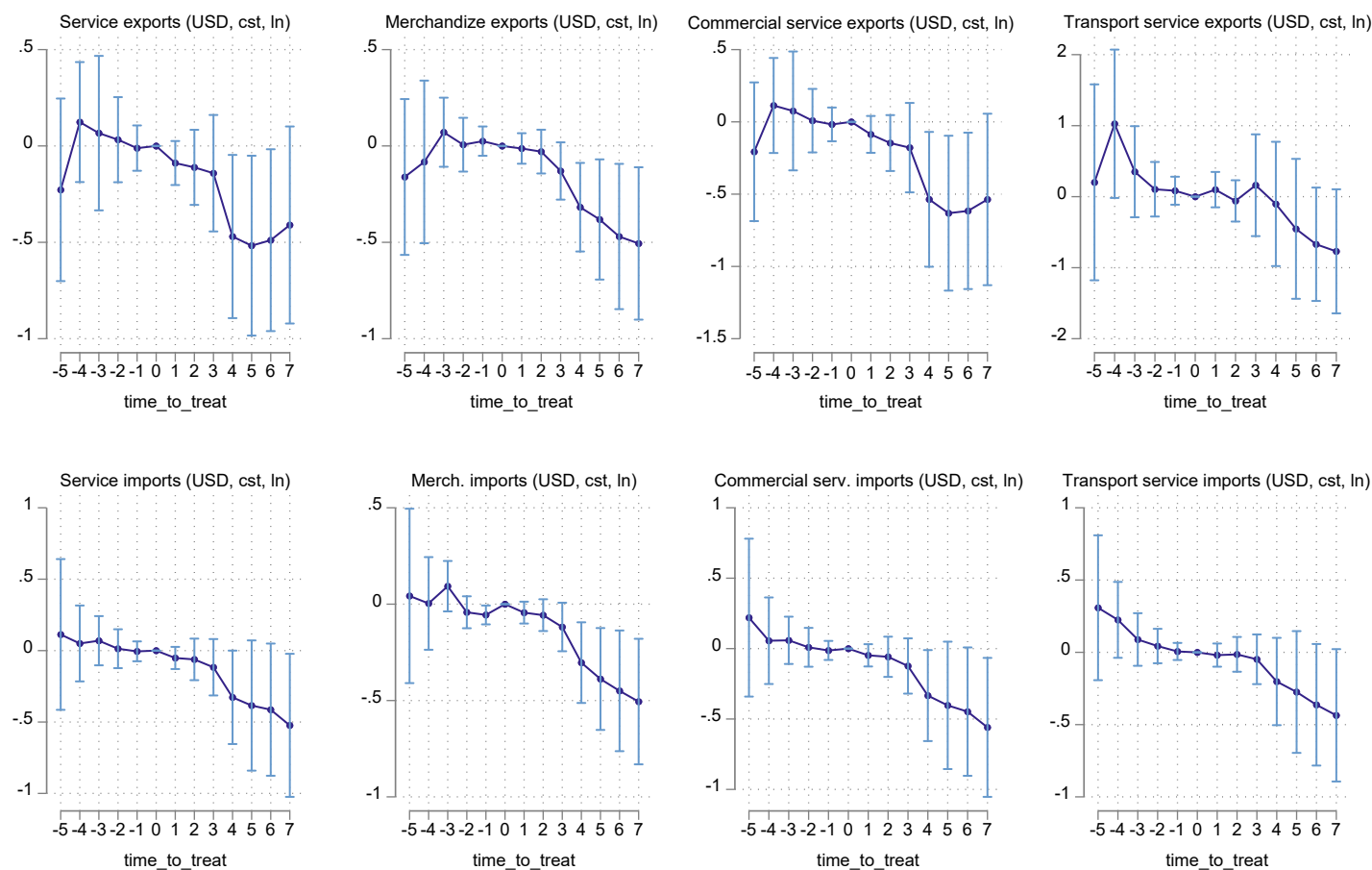
These results reinforce the view that in digitally connected economies—especially in low- and middle-income countries where redundancy in connectivity is limited—SMC disruptions can undermine both the export capacity and the import of critical goods and services. The findings highlight the strategic importance of resilient connectivity infrastructure, redundancy in international links, and contingency planning to mitigate the economic cost of such outages.

²¹ Raw data on cable disruptions was collected and treated from the Subtel forum <http://subtelforum.com/category/cable-faults-maintenance/>, Akamai's reports on the "State of Internet Connectivity", and completed by manual Internet searches.

²² 43 from ECA, 32 from SSA, 20 from LAC, 14 from EAP, 6 from MENA, and 2 from SA.

²³ See <https://blog.telegeography.com/oceaniq-submarine-cable-faults-interview>

FIG. 3.14. TRADE RESPONSES TO SMC FAILURES IN LOW AND MIDDLE-INCOME COUNTRIES, DYNAMIC ESTIMATIONS, 2008-2020.



Source: Author. Notes: Figures report event-time coefficients with 95% confidence bands; specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence. Raw data on cable disruptions drawn from the Subtel forum <http://subtelforum.com/category/cable-faults-maintenance/>, Akamai's reports on the "State of Internet Connectivity", and completed by manual Internet searches. Trade data come from the World Bank's World Development Indicators (accessed via the *wbopendata* Stata command). The sample includes 1,599 observations across 123 countries (41 high-income, 67 middle-income, and 15 low-income), covering 44 from ECA, 36 from SSA, 21 from LAC, 14 from EAP, 6 from MENA, and 2 from SA. A five-year placebo window is included to test for parallel trends. The treatment is defined at the country-year level as the number of episodes in which a submarine-cable failure (outage or break) generates a measurable loss of international connectivity for that country. Therefore, cable failure attribution follows the principle of material impact rather than physical proximity. Under this approach, a single submarine cable failure affecting multiple countries is recorded

as several country-specific events, with affected nations sometimes located far from the break site. The coefficients trace out the effect of a one-unit increase in treatment intensity at event time k . See Cariole (2026) for methodological details.

4.5. Discussion and policy implications

Key findings and policy implications, discussed in this subsection, are synthesized in Box 2. Evidence presented stress that the global rollout of the SMC infrastructure has expanded international bandwidth, improved digital connectedness, and created new opportunities for DTs diffusion. However, as highlighted by Imbruno et al. (2025), these opportunities are not evenly realized across countries and firms. While SMC expansion stimulates export participation in many developed economies, it can have the opposite effect in developing countries. This divergence reflects deeper asymmetries in the ability to absorb and leverage DTs: in advanced economies, firms often possess the complementary capabilities—technological readiness, skilled labor, access to finance—that enable them to convert better connectivity into productivity gains, innovation, and trade competitiveness. In developing contexts, by contrast, structural constraints limit the capacity to turn connectivity into digital adoption, and digital adoption into trade dividends.

Evidence from Cariolle & Da Piedade (2023) underscores that it is not just the presence of digital infrastructure that matters, but the quality of connectivity. Their measure of digital connectedness—the share of world GDP to which a country is directly linked through SMCs—shows that countries connected to major economic hubs achieve more sophisticated and diversified exports. For SSA, the benefits are especially pronounced in geographically remote economies, suggesting that SMC links to major hubs can partially substitute for physical proximity. Again, these benefits depend on complementary enablers—such as human capital, logistics, and regulatory capacity—that determine whether connectivity translates into transformative DT adoption.

The fragility of SMC-trade nexus becomes evident when infrastructure fails. The empirical results presented in Figure 3.14 show that SMC disruptions—whether caused by cable breaks or faults—lead to sustained and broad-based trade losses. These effects reflect heightened information frictions, the disorganization of payment systems, and reduced access to foreign inputs, to which small and medium-sized exporters, often early adopters of digital tools but with limited resilience to telecommunications disruptions, are probably disproportionately exposed. A single fault can thus remove a large share of available bandwidth, leading to amplifying and persistent trade losses observed in the data.

These findings carry two important implications for the broader question of the trade impacts of digital technology diffusion. First, closing the *infrastructure gap*—by expanding cable coverage and bandwidth—is a necessary but insufficient condition for inclusive digital trade gains. Without complementary policies to close the *technology gap* (ensuring that advanced DTs can be integrated into national production systems) and the *usage gap* (ensuring that firms and individuals can afford, understand, and effectively use these technologies), new infrastructure can exacerbate disparities in how trade benefits from DT adoption are distributed. Second, the resilience of the SMC network is a key determinant of the persistence and robustness of these trade benefits. In regions such as SSA, where connectivity depends on a small number of SMC systems with limited redundancy, a single disruption can significantly erode export capacity and access to imported inputs, offsetting years of trade integration progress.

Policy priorities should therefore combine infrastructure investment with capability-building to ensure that the trade benefits of DT adoption are both inclusive and resilient. This includes fostering competition in Internet markets to lower prices, strengthening regulatory oversight to

ensure cost pass-through, supporting SME access to digital tools and finance, and investing in digital literacy and workforce training. At the same time, building resilient SMC networks—through diversified routes, improved regional interconnection, and local maintenance capacity—is essential to safeguard trade competitiveness against connectivity shocks. Only by addressing these multiple dimensions can SMC infrastructure act as a catalyst for sustainable and inclusive digital trade, rather than a source of new vulnerabilities in the global economy.

| Box 2. Key findings and policy implications | |
|----------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Main messages: | |
| Heterogenous trade impacts | Global SMC rollout expands bandwidth and DT diffusion, but export gains are uneven: SMCs boost export participation in many advanced economies, while effects can be weak or even negative in developing countries due to weaker absorptive capacity. |
| Role of absorptive capacity | Advanced economies convert connectivity into productivity, innovation, and trade because firms have skills, finance, and technological readiness; in many developing countries, structural constraints prevent connectivity → DT adoption → trade gains from fully materializing. |
| Quality of connectivity | It is not just infrastructure presence but also quality of digital connections (links to major economic hubs) that matters: countries more directly connected via SMCs export more sophisticated and diversified products, with especially strong gains for remote SSA economies. |
| Digital vulnerability | SMC breaks and faults cause persistent, broad-based trade losses by raising information frictions, disrupting payments, and limiting access to foreign inputs; SMEs, often early DT adopters but less resilient, are particularly exposed. |
| Mind the digital gaps | Closing the infrastructure gap alone is insufficient: without closing technology and usage gaps, new SMC capacity can widen disparities in who benefits from digital trade. |
| Resilience priority | Trade gains from DTs depend on the resilience of the SMC network; in regions with few cables and limited redundancy, a single failure can undo years of trade integration. |
| Digital policy mix | Combine: (i) infrastructure investment and more resilient, redundant SMC networks; (ii) competition and regulation to lower prices and ensure cost pass-through; (iii) SME access to digital tools and finance; (iv) digital skills and workforce training, so digital trade gains are both inclusive and sustained. |

5. Tapping into the last-mile: economic impacts of access, adoption and diffusion of digital technologies

The previous section examined how first-mile infrastructure—particularly SMC systems—underpins DT diffusion and enables countries to participate in the global digital economy. Yet, the transformative potential of this upstream capacity ultimately depends on whether it reaches individuals, firms, and institutions through reliable, affordable, and accessible last-mile

infrastructure. Without effective last-mile delivery, the gains from large-scale investments in SMCs, backhaul, and national backbone networks cannot be fully realized, and the diffusion of DTs remains constrained.

Because DTs are network goods, their economic impact depends on the scale of adoption (Björkegren, 2019; Björkegren & Karaca, 2022): the more people, firms, and administrations use a technology, the more valuable it becomes for each user. The potential for scaling up depends heavily on the type of last-mile infrastructure in place and its interaction with the local environment. In low-income and rural areas, mobile networks can be rolled out more quickly and at lower cost than fixed broadband, making them the main channel for delivering basic services such as voice, SMS, and USSD-based mobile money. By contrast, more advanced, data-intensive applications—such as cloud computing, high-definition video conferencing, or AI tools—require high-speed fixed broadband, which is typically concentrated in wealthier and more densely populated urban areas.

These infrastructure–context interactions determine not only which technologies diffuse, but also the kinds of innovations that emerge (Aker & Cariolle, 2023). Rural and remote areas face additional barriers—lower population density, weaker purchasing power, and limited digital literacy—that slow adoption even when coverage is available. Yet these same factors can magnify the impacts once adoption occurs: for example, in isolated rural communities, mobile telecommunications can sharply reduce market isolation, and digital financial services can provide unprecedented access to payments, credit, and savings (Aker, 2010; Suri et al., 2023). By contrast, in urban centers, high user density and greater demand for digital services foster faster adoption, stronger network and spillover effects.

The sections that follow analyze these dynamics, beginning with mobile coverage in rural areas, where mobile networks have often been the primary gateway to DT adoption and have generated measurable impacts on food market integration, agricultural productivity, gender dynamics in labor markets, and household economic diversification.

5.1. Mobile network coverage, mobile phone adoption, and rural transformations

5.1.1. Accessing market information through mobile phone in rural areas

Before the deployment of mobile networks, rural populations in low-income countries had few options for accessing market information—mainly through radio, newspapers, physical travel to markets, or, for the few with landline access, calling family and friends (Aker, 2011; Aker & Mbiti, 2010). The high time and monetary costs of obtaining price data led to significant spatial price dispersion, with information asymmetries contributing to speculative behavior in some markets (Araujo Bonjean & Simonet, 2016). The expansion of mobile coverage and the diffusion of mobile phones brought a transformative effect to agricultural markets by significantly reducing price dispersion, enabling producers to access market prices at lower cost (Jensen, 2007; Aker, 2010).

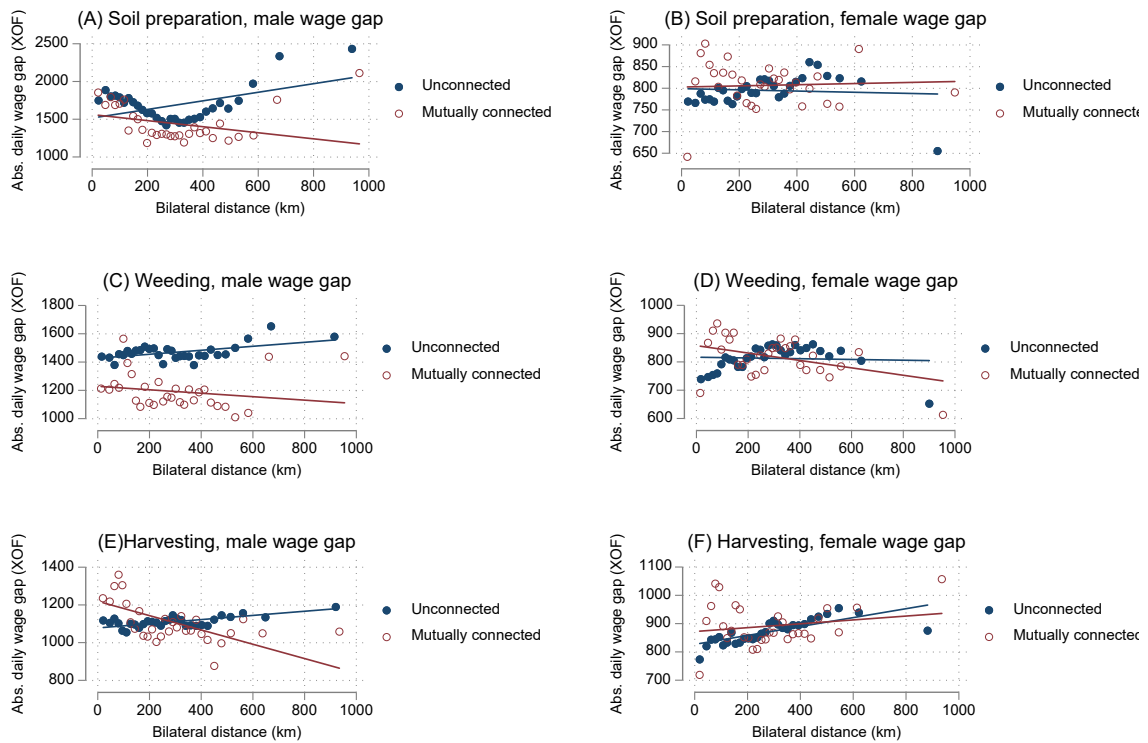
Mobile connectivity can improve agricultural output and input market functioning through several mechanisms. By lowering the cost of obtaining and transmitting information, mobile phone adoption by market participants enables them monitoring prices across multiple, spatially dispersed markets more frequently and at lower cost. This reduces information frictions, allowing both farmers and traders to identify more profitable trading opportunities and

avoid markets with unfavorable prices. As shown by Aker (2010) in Niger and Jensen (2007) in India’s fisheries sector, such reductions in search costs translate into narrower price dispersion (see Appendixes B.1 and B.2), higher and more stable producer prices, and less waste from unsold commodities. Evidence from Tack and Aker (2014) further shows that mobile phone coverage increases the number of markets in which traders actively search and the number of market contacts they maintain, especially for larger traders and those in more isolated areas, magnifying the efficiency gains. Aker and Fafchamps (2014) find similar effects for farmgate prices, highlighting how connectivity can increase farmers’ bargaining power. From a dynamic perspective, these benefits are hence not uniform: adoption often starts with better-off or more connected traders, meaning that while mobile coverage can reduce spatial inequalities in prices, it can also widen gaps between early and late or non-adopters.

A similar role for mobile connectivity emerges in agricultural production factor markets. Easier access to information on land, labor, and input availability and quality can help reduce spatial price disparities. Although direct empirical evidence on these markets is scarce, analysis of agricultural daily wage gaps—disaggregated by gender and task (soil preparation, weeding, and harvesting)—conducted in Cariolle & Carroll (2025b) across the eight West African Economic and Monetary Union (WAEMU) member states provides interesting insights (Figure 5.1). The graphs plot the absolute wage differential between pairs of enumeration areas (EAs) against the geographic distance separating them, distinguishing between pairs that are mutually connected by mobile networks and those that are not. In unconnected EAs (blue dots), wage gaps generally increase with geographic distance, reflecting market segmentation.

In contrast, in connected EAs (pink circles), the relationship is generally flatter and, in some cases, turns negative—most notably for male wages in soil preparation, harvesting – which is typically male-dominated tasks – and for female wages in weeding, a task largely undertaken by women. This pattern suggests that mobile connectivity has the strongest equalizing effect in agricultural tasks where labor markets are segmented by gender, helping to reduce spatial wage disparities within these segments.

FIG. 5.1. MOBILE CONNECTIVITY AND THE DISTANCE-WAGE GAP NEXUS IN WEST AFRICAN AGRICULTURAL LABOR MARKETS, BINNED SCATTER PLOTS.



Source: Cariolle & Carroll (2025b). Based on data from the *Enquêtes Harmonisées sur les Conditions de Vie des Ménages* (EHCVM) conducted in 2018-2019. Wage information is collected at the enumeration area (EA) level. Panel sample sizes: (A) 3,032 paired EAs; (B) 2,658; (C) 2,974; (D) 2,742; (E) 2,859; (F) 2,753. Correlation plots conditional on controlling for night-time light density in paired areas, its bilateral differential, a common urban status dummy, a common-department dummy, and a common-season dummy.

5.1.2. Access to mobile connectivity and gender disparities in agricultural labor markets

In addition to fostering wage equalization across areas, mobile phone-enabled access to information can facilitate farmers' use of hired labor while also enhancing the bargaining power of agricultural workers. For women, these benefits can be particularly significant. Mobile technologies may allow them to monetize tasks that were previously unpaid or dominated by men and to negotiate higher wages (Ngoa & Song, 2021; Cariolle & Dsouza, 2025).

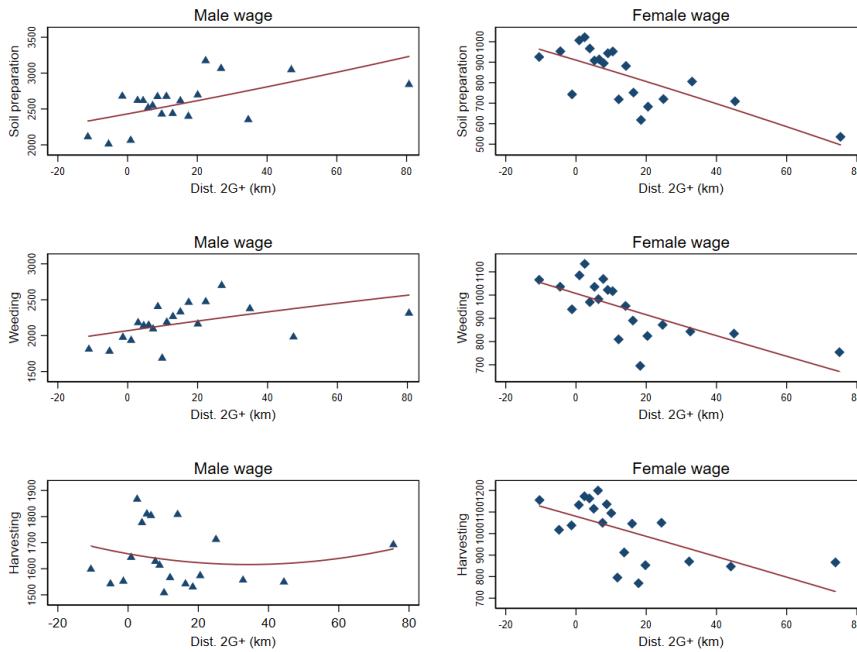
The relationship between mobile connectivity and wage levels, however, remains context-dependent—shaped by local economic development, labor mobility, and power dynamics between employers and workers. Still, the graphical evidence in Figure 5.2 points to a consistent positive correlation between enumeration area (EA)'s proximity to the 2G+ mobile network and female wages across all three agricultural tasks examined.²⁴ This includes soil preparation—a physically demanding activity typically performed by men—where women's earnings rise noticeably in areas closer to mobile coverage.

By contrast, the association between mobile network proximity and male wages is weaker and more heterogeneous across tasks. This asymmetry suggests that mobile connectivity may deliver disproportionate gains to women, possibly by expanding their access to wage labor opportunities and altering gender norms in agricultural employment. Supporting this interpretation, Figure 5.3 shows that the gender wage gap increases with distance from the

²⁴ Correlation conditional on controlling for the EA's geographical distance to the closest urban center.

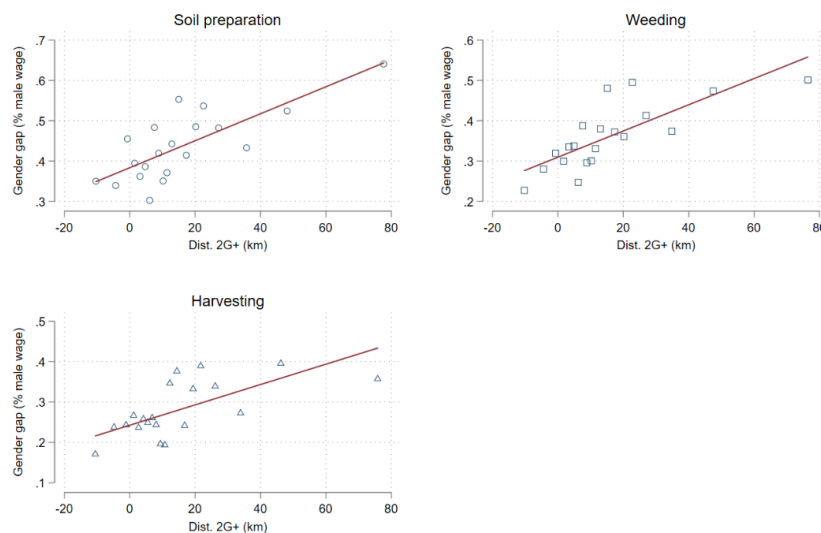
2G+ network for all three tasks. The upward slopes indicate that women’s wages fall further behind men’s in remote, less connected areas—highlighting the potential of mobile phone access to reduce gender-based wage inequality in rural labor markets.

FIG. 5.2. MOBILE NETWORK PROXIMITY AND WAGE LEVELS IN WEST AFRICAN AGRICULTURAL LABOR MARKETS, BINNED SCATTER PLOTS.



Source: Cariolle & Carroll (2025, forthcoming). Based on data from the Enquêtes Harmonisées sur les Conditions de Vie des Ménages (EHCVM) conducted in WAEMU member states in 2018-2019. Controls include geographical distance to the closest urban center.

FIG. 5.3. MOBILE NETWORK PROXIMITY AND GENDER WAGE DIFFERENTIAL IN WEST AFRICAN AGRICULTURAL LABOR MARKETS, BINNED SCATTER PLOTS.



Source: Cariolle & Carroll (2025b). Based on data from the Enquêtes Harmonisées sur les Conditions de Vie des Ménages (EHCVM) conducted in WAEMU member states in 2018-2019. Controls include geographical distance to the closest urban center.

5.1.3. General equilibrium effects of mobile technology diffusion

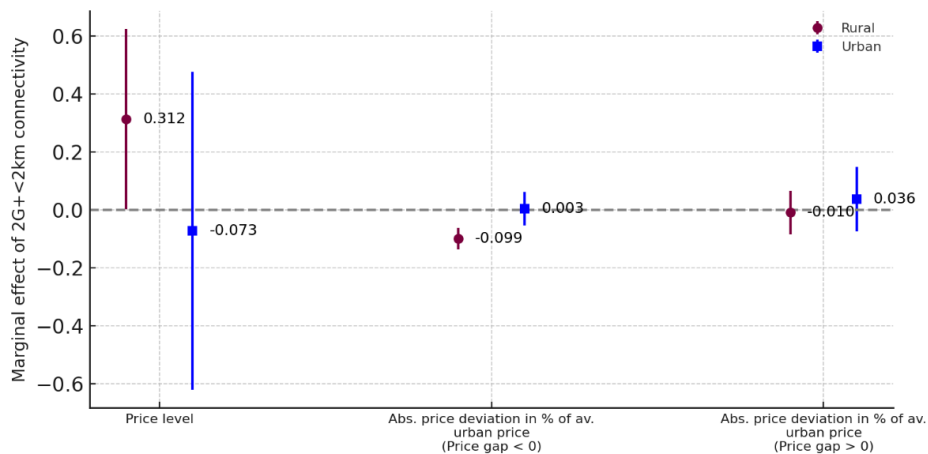
By enhancing access to information about farm and non-farm labor opportunities, mobile technology diffusion encourages households to diversify their economic activities, possibly shifting labor toward more productive and profitable non-agricultural sectors (Gollin et al., 2014; Deininger et al., 2018; Shamdassani, 2021; Cariolle & Carroll, 2024; Bahia et al., 2023, 2024). This shift can operate in relation to improvements in agricultural productivity, which increase local demand for goods and services such as manufacturing, construction, retail, and education, thereby promoting labor reallocation beyond farming activities (Emerick, 2018). Additionally, access to mobile money services significantly enhance financial inclusion, particularly for households without formal banking access, by facilitating monetary transactions, savings, and investments (Suri et al., 2023). Consequently, widespread adoption of mobile technologies and related services generates benefits across multiple markets.

In a recent study, Cariolle and Carroll (2024) put in evidence general equilibrium effects of mobile connectivity on rural livelihoods in West Africa, focusing on demand-side channels. Using data on nearly 60,000 households across eight WAEMU countries, they show that better mobile coverage reduces food price dispersion by enabling a catch-up effect toward urban price levels (Figure 5.4). Contrary to previously-mentioned studies focused on supply-side (producers and traders) mechanisms, this convergence is primarily driven by increased rural household food demand: mobile phone owners consume more food products and purchase more from markets, and rely less on self-produced food, with the shift toward market-based consumption being especially marked in rural areas.

Two main mechanisms explain this rising demand. First, mobile money services expand financial inclusion, easing access to liquidity for consumption and investment. Second, mobile connectivity promotes income diversification into off-farm activities (Figure 5.4). The data reveal that mobile-connected households are more engaged in both farming and non-farm activities, with the strongest growth in off-farm participation occurring in rural areas. Connectivity also fosters the creation of non-agricultural enterprises and improves profit margins from unprocessed goods among rural and farming households. Conversely, it is associated with declining sales of processed goods and farm products, suggesting a reallocation of household labor away from value-added agricultural production toward more flexible, trade-oriented activities.

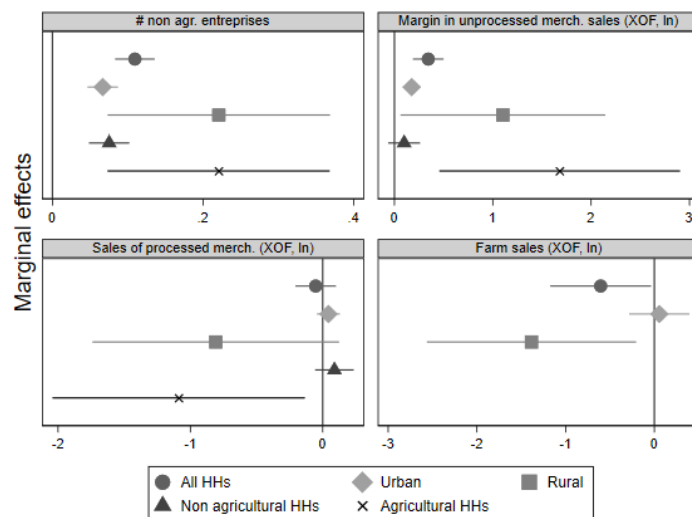
Importantly, the study also highlights that the benefits of mobile connectivity are, again, unevenly distributed. Rural households without mobile phones experience a decline in food consumption, suggesting they are facing negative externalities due to higher food prices. This reflects a persistent usage gap—even where last-mile infrastructure exists, barriers such as affordability, digital literacy, and access to complementary services limit adoption and prevent certain households from benefitting mobile dividends. As a result, mobile connectivity can simultaneously foster rural market integration and economic diversification for some, while deepening inequalities for others. Addressing these gaps is therefore essential if last-mile infrastructure is to deliver inclusive digital technology diffusion and ensure that scaling-up opportunities generate broad-based benefits rather than reinforcing existing divides.

FIG.5.4. MARGINAL EFFECTS OF MOBILE NETWORK CONNECTIVITY ON FOOD PRICE LEVEL IN RURAL AND URBAN AREAS IN THE WEAMU, IV ESTIMATES.



Note: Estimates from Cariolle & Carroll (2024).

FIGURE 5.5. MOBILE CONNECTIVITY AND HH INCOME DIVERSIFICATION, MARGINAL EFFECTS, IV ESTIMATIONS.



Note: Drawn from Cariolle & Carroll (2024).

5.2. Internet diffusion and spillover effects on manufacturing in developing countries.

In the previous section, we examined how mobile phones access—by lowering information frictions and fostering financial inclusion in rural areas—can trigger broad general equilibrium effects, from improved agricultural market efficiency to shifts in rural labor force allocation. These impacts were largely shaped by the suitability of mobile technologies to low-density, resource-constrained environments, where feature phones and USSD-based applications can achieve wide reach despite limited infrastructure and absorptive capacities.

In urban and industrializing contexts, however, the diffusion dynamics and spillover potential of digital technologies differ markedly. Here, fixed or mobile broadband Internet becomes the critical infrastructure, supporting data-intensive applications, integration into global value chains, and the transfer of tacit and codified knowledge across firms. The nature of spillovers also shifts: in rural agricultural economies, gains often arise from reducing geographic isolation and enabling basic market participation; in manufacturing and service hubs, spillovers are

more closely tied to agglomeration economies, network effects among dense clusters of users, and cross-industry linkages along supply and value chains.

This section examines how Internet diffusion in urban and peri-urban manufacturing centers generates local productivity spillovers, distinguishing between intra-industry effects—arising from knowledge sharing within a sector—and inter-industry effects—linked to complementarities across sectors. It also considers how the scale and distribution of these spillovers depend on firms' digital absorptive capacity, potentially reinforcing or narrowing existing divides in industrial competitiveness.

5.2.1. Internet spillovers in agglomerations

The diffusion of the Internet technologies generates benefits that extend beyond direct users through local spillover effects. Evidence from the literature on agglomeration economies (Marshall, 1890; Jacobs, 1969; Glaeser et al., 1992; Frenken et al., 2007) shows that these spillovers often materialize within geographically bounded areas, where dense networks of firms and workers facilitate the transmission of tacit knowledge, good practices, and innovations. While Internet technologies enable the exchange of codified information across long distances, the effective transfer and absorption of non-codified, experience-based knowledge typically requires complementary face-to-face interactions (Gaspar & Glaeser, 1998; Storper & Venables, 2004; Wu et al., 2021).

In this context, spatial Internet spillovers can be classified as i) intra-industry spillovers, where firms in the same location and industry share Internet-based innovations, practices, and know-how; and ii) Inter-industry spillovers, where the adoption of Internet technologies spreads across proximate industries, strengthening linkages with upstream suppliers and downstream clients or enabling the emergence of entirely new inter-industry connections (Marsh et al., 2017).

The Internet's nature as both a GPT and a network good underlies these mechanisms. The value of Internet technologies adoption increases with the size of the local user base: a larger number of connected firms and workers within a city or industrial cluster raises the frequency and diversity of interactions (Katz & Shapiro, 1985). Empirical studies highlight this dynamic in developing countries—Björkegren (2019) in Rwanda and Wu et al. (2021) in China show that network size amplifies the growth and welfare impacts of Internet adoption.

However, the strength of these spillovers depends critically on digital absorptive capacity—the ability of firms and industries to integrate Internet technologies into their production processes and organizational structures, as already discussed. This capacity can be constrained by shortages of digital skills, limited innovation efforts, time lags in realizing returns from technology integration, weak exposure to international competition, or insufficient investment in research and development (Görg & Greenaway, 2004; Hjort & Poulsen, 2019; Marsh et al., 2017; Paunov & Rollo, 2015, 2016). Firms unable to adapt may even experience relative revenue losses, as competitors benefit from efficiency gains and market expansion enabled by digital tools. Over time, these dynamics can contribute to structural change—intensifying disparities between cities with high and low Internet penetration, and accelerating the decline of traditional industries made obsolete by technological shifts (Choi et al., 2020; Diao et al., 2019; McMillan et al., 2016; Wu et al., 2021).

In sum, the diffusion of Internet technologies in manufacturing and service hubs can act as a powerful driver of industrialization and economic transformation, but the magnitude and distribution of these benefits are mediated by local network size and firms' absorptive

capacities. The next subsection examines empirical evidence on these spillovers across firms from a large sample of developing economies, distinguishing between intra- and inter-industry effects.

5.2.2. Spillover effect of email technology diffusion in the manufacturing sector

While the direct benefits of Internet adoption for firms—through reduced transaction costs, improved information flows, and enhanced innovation—are well established (Houngbonon et al., 2022), the local diffusion of these technologies can also generate significant spatial spillover effects across firms and industries. Descriptive evidence from a large sample of developing and transition economies, shown in Figure 5.6, reveals a strong positive correlation between the local share of firms using email and manufacturing firms' sales and sales per worker. This relationship suggests that as more firms in a location adopt Internet-based tools, network effects and knowledge spillovers may amplify the gains from adoption, motivating a closer causal investigation.

The manufacturing sector, at the core of industrialization processes in developing countries, offers a particularly relevant setting to investigate these dynamics. Despite substantial evidence of Internet benefits for service industries (Houngbonon & Mothobi, 2025), its role in fostering manufacturing performance in low- and middle-income countries has been less explored. Yet, the potential for knowledge spillovers and productivity gains in manufacturing could be substantial, given its higher scope for technological upgrading compared to services (Glaeser et al., 1992).

To study spatial Internet spillovers on manufacturing firms, Cariolle and Le Goff (2023) examine how the local incidence of email use—the most widespread Internet technology among firms in developing contexts—affects firm performance.²⁵ Using firm-level data from 44,073 manufacturing firms across 562 locations in 109 developing and transition economies over 2006–2018, the authors show that local share of firms using email generates substantial productivity spillovers for manufacturing firms. Baseline estimates indicate that a 10-percentage point increase in the share of local firms using email raises manufacturing firms' sales and sales per worker by around 40%. These gains are primarily driven by intra-industry spillovers: firms benefit most when digital adoption spreads among peers in the same industry and location. This result suggests that knowledge transfer, imitation, and shared good practices within the sector are key mechanisms.

By contrast, the analysis reveals the presence of U-shaped inter-industry spillovers depending on the size of the local network of email users outside the firm's industry: below an email penetration threshold of roughly 45–53% of firms in locations, only a small subset of digitally-enabled adopters may capture market share or erect entry barriers, while above it, larger user networks generate sufficient demand and coordination benefits to outweigh competitive losses. Intra-industry spillovers do not display such a threshold pattern, consistent with mechanisms driven more by knowledge spillovers than by network effects.

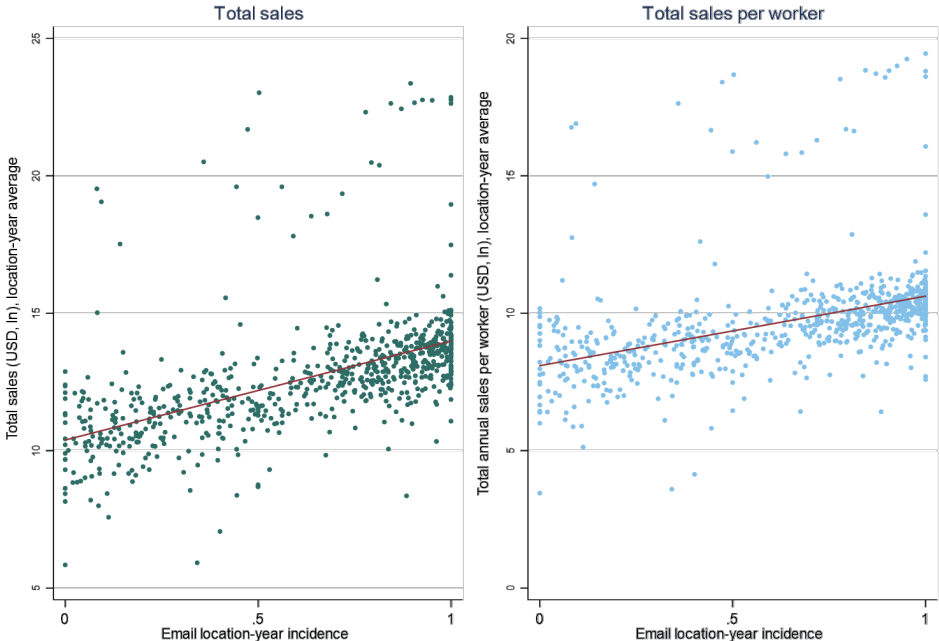
The role of absorptive capacity is also emphasized. When splitting inter-industry effects by firm orientation, results show that negative spillovers are concentrated among inward-oriented firms (single-plant, domestically focused, no foreign ownership), while outward-oriented firms

²⁵ Their identification strategy relies on an instrumental variable set up exploiting the arrival of SMCs and occurrence of SMC outage as exogenous source of connectivity, weighted by the location's distance to the closest connectivity node (SMC landing stations or internet exchange points), to predict local email diffusion.

(exporting, foreign-owned, multi-plant) are able to leverage cross-industry connectivity gains even in less digitalized environments. Outward-oriented firms are more likely to operate in contexts where Internet incidence reaches the positive spillover threshold, highlighting the interaction between digital diffusion, firm capabilities, and global linkages.

Overall, the results suggest that local Internet diffusion can substantially boost manufacturing performance in developing and transition economies, but the gains are uneven. Intra-industry adoption yields consistently positive effects, while inter-industry gains require a critical mass of adoption and are disproportionately captured by firms with greater absorptive capacity and external linkages. These findings underline the importance of not only expanding Internet access but also promoting broad-based adoption across sectors and enhancing firms' capacity to integrate digital tools into their operations.

FIG.5.6. LOCAL INCIDENCE OF EMAIL USE AMONG FIRMS AND MANUFACTURING FIRMS' PERFORMANCE.



Source: Drawn from Cariolle & Le Goff (2023). World Bank WBES data and authors' calculation based on 739 locations in 109 developing countries.

5.3. Discussion and policy implications

Key findings and policy implications, discussed in this subsection, are synthesized in Box 3. The results presented show that the local diffusion of digital technologies—whether through mobile coverage in rural economies or broadband Internet in urban manufacturing hubs—can generate powerful spillover effects, but these effects are uneven across contexts, sectors, consumers and producers. In rural settings, mobile connectivity reduces information frictions, integrates markets, and facilitates diversification into non-farm activities, with especially strong impacts on women's labor market outcomes. In urban and industrial contexts, broadband Internet diffusion boosts manufacturing firm performance, primarily through intra-industry spillovers, while inter-industry gains materialize only once a critical mass of adoption is reached.

These findings have two important implications for the broader debate on digital technology diffusion. First, network effects require scale: in both rural and urban cases, the full benefits of digital adoption emerge only when enough users participate, whether they are farmers, traders, or manufacturing firms. This highlights the need for policies that promote broad and inclusive adoption, not just infrastructure rollout. Second, absorptive capacity shapes who benefits: in manufacturing, outward-oriented firms capture the largest inter-industry internet spillovers, while inward-oriented firms may even face competitive losses in early stages of diffusion. Similarly, in rural markets, households without mobile access can face rising cost of living in areas being covered by the network, without enjoying the corresponding digital dividends.

From a policy standpoint, these findings stress three priorities. First, interventions should aim to close the digital penetration gap, particularly in lagging regions and industries, to ensure that positive spillovers materialize broadly rather than reinforcing structural divides. This may require targeted infrastructure investments, affordability programs, and digital literacy initiatives tailored to different user groups. Second, enhancing absorptive capacity—through skills training, innovation support, and exposure to competitive markets—is essential for firms and workers to benefit from technological diffusion. Without such capacity, Internet and mobile adoption risks translating into market share losses or de-industrialization in less-prepared sectors. Third, complementary markets and enabling institutions must be in place. Reliable electricity, regulatory clarity, and integration with financial and logistical services are critical for sustaining digital usage and scaling benefits.

Therefore, as suggested by Aker and Cariolle (2023), digital-for-development policies should avoid technocentric, one-size-fits-all approaches, and instead design and support interventions that are context-specific, piloted at small scale, and rigorously evaluated before broader rollout. Evidence on heterogeneous effects and spillovers is particularly critical for deciding when and how to scale up digital innovations: scaling too early, without sufficient network penetration or absorptive capacity, risks concentrating gains among a few well-positioned actors while excluding the rest. The ultimate goal should not simply be to expand access, but to build inclusive digital ecosystems where technologies—once scaled—serve as engines of structural transformation, rather than reinforcing existing inequalities by leaving behind those unable to connect or adapt.

Box 3. Key findings and policy implications

Main messages:

| | |
|------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Spillover effects | Local diffusion of mobile (rural) and broadband (urban) generates strong spillovers, but benefits are uneven across contexts, sectors, firms, and households. |
| Rural impacts | Mobile coverage reduces information frictions, integrates markets, and supports non-farm diversification, with especially strong gains for women; non-connected households in covered areas can face higher living costs without digital dividends. |
| Urban/manufacturing impacts | Broadband boosts manufacturing performance mainly via intra-industry spillovers; inter-industry gains appear only after a critical mass of adoption, and outward-oriented firms benefit most. |
| Network effects | Digital network effects require scale: full benefits arise only when enough users adopt, so narrow or partial diffusion can limit spillovers and widen divides. |
| Absorptive capacity | Skills, market orientation, and organizational capacity determine who gains; poorly prepared firms and workers may face competitive losses or de-industrialization pressures. |
| Policy priorities | (i) Close digital penetration gaps in lagging regions/sectors; (ii) strengthen absorptive capacity (skills, innovation support, exposure to competition); (iii) ensure complementary infrastructure and institutions (electricity, regulation, finance, logistics). |
| Policy approach | Avoid technocentric, one-size-fits-all rollouts; use context-specific, piloted, and rigorously evaluated interventions to build inclusive digital ecosystems rather than reinforce existing inequalities. |

6. Conclusion

Digital technologies generate economic gains only when they are widely adopted, connected to high-capacity and reliable networks, and accessible to firms and households across different income levels and locations. As both general-purpose technologies and network goods, their impact can be systemic, depending on how many users are connected to each other's, the capacity and resilience of the networks they use, and whether those users have the skills and resources to integrate DTs into production processes and daily activities. Once adoption of a technology—such as the Internet—or its applications—like digital platforms—reaches a critical mass, it generates spillovers that spread among individuals, within and between firms and industries, and across different markets.

This chapter has shown that while the expansion of mobile networks in developing economies has greatly improved access to basic digital services—particularly in Sub-Saharan Africa—persistent gaps in infrastructure, affordability, and digital capabilities limit the ability of many countries to move beyond basic uses and capture the broader productivity and trade gains associated with digitalization.

At the core of these constraints is the international connectivity backbone provided by SMC systems. These undersea fiber-optic links form the first-mile infrastructure of the global

Internet, enabling individuals, firms, and countries to participate in the digital economy. Their rapid expansion over recent decades has reduced connectivity costs—first by lowering international calling prices in the early 2000s, and later, with the rollout of high-capacity fiber lines in the late 2000s, by improving access to data-intensive applications and opening new trade opportunities, particularly for countries directly linked to major global economic hubs. Yet these gains are uneven: in many developing economies, smaller and inward-oriented firms face higher adjustment costs and may lose market share in the early phases of digital diffusion. In addition, as the large-scale outages of 2024 have shown, this backbone remains highly vulnerable, with a limited number of critical routes carrying most international traffic. Such fragility imposes immediate economic costs and creates a long-term drag on digital adoption, especially where redundancy is low and regional interconnection is weak.

Within countries, last-mile infrastructure determines which technologies reach end-users and how quickly they diffuse. In rural areas, mobile coverage can reduce market isolation, integrate food markets, and expand women’s wage opportunities—though households excluded from adoption may face adverse price effects. In urban manufacturing hubs, broadband penetration raises productivity primarily through intra-industry spillovers, while inter-industry benefits require a critical adoption threshold and are captured disproportionately by outward-oriented firms.

Thus, the evidence presented throughout this report highlights that simply increasing bandwidth capacity or infrastructure coverage is necessary but not sufficient. Three interrelated gaps—infrastructure, technology, and usage—emerge as critical obstacles to inclusive digital transformation. The infrastructure gap encompasses not only physical availability but also the strategic quality of international and domestic links. The technology gap concerns the accessibility of advanced applications, which hinge on high-speed, reliable broadband. The usage gap reflects skills, affordability, and institutional capacity to translate connectivity and adoption into tangible socio-economic gains. Bridging these gaps is essential if developing countries are to move from basic, mobile-centric digitalization process towards a higher value, inclusive, innovation-enabling digital ecosystem.

In short, digital development strategies should be designed with *confidence and humility*—grounded in context-specific diagnostics, piloted before mass rollout, and accompanied by complementary policies that ensure DTs function as engines of structural transformation for all, rather than as catalysts of advantage for the already connected.

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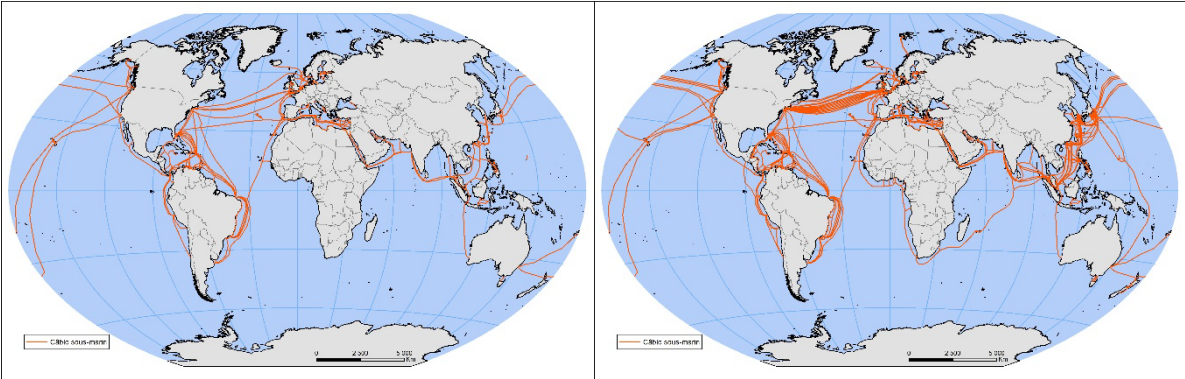
Appendixes

A. Submarine cable rollout and vulnerabilities

A.1. Submarine cable expansion over time and space.

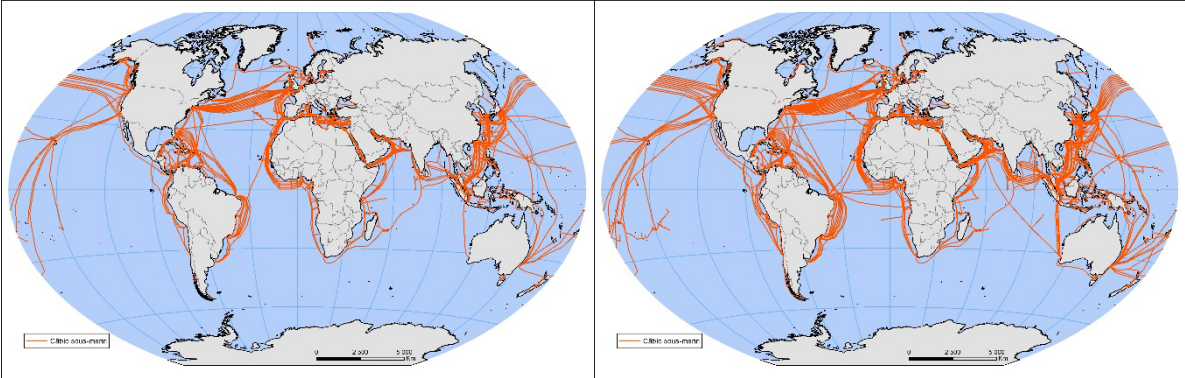
2000

2005

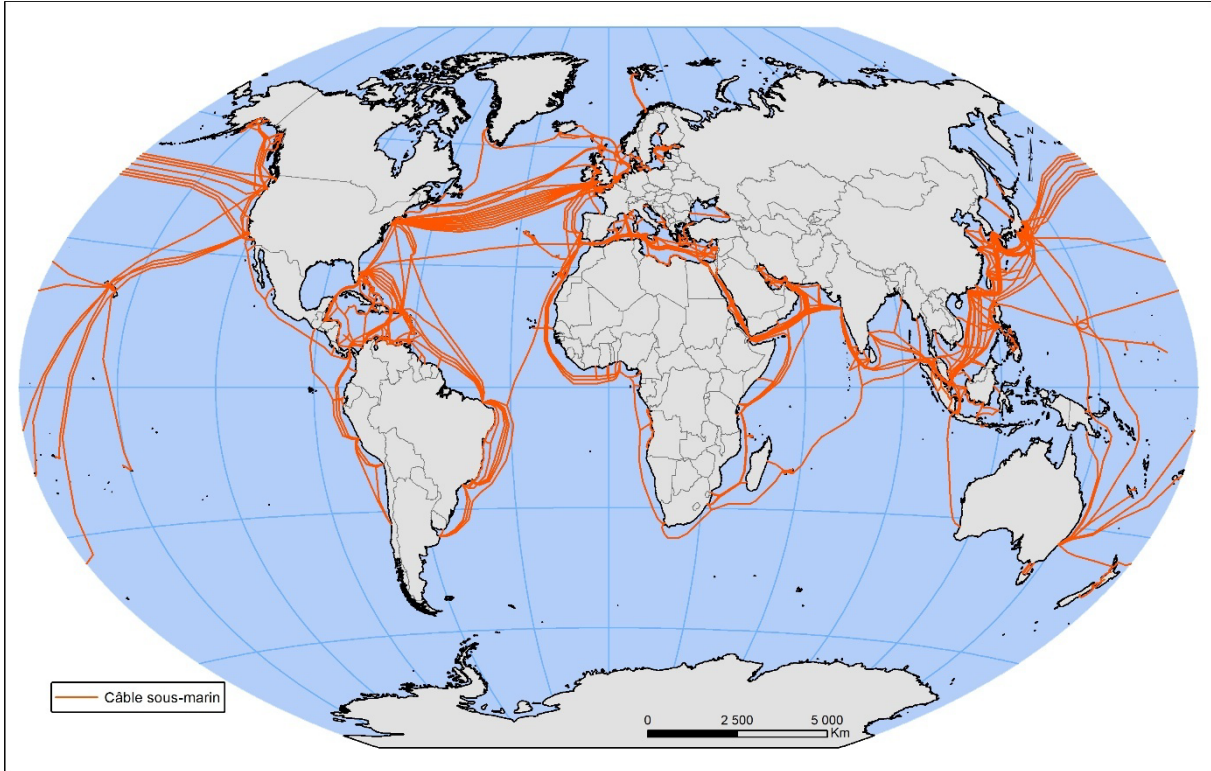


2010

2015

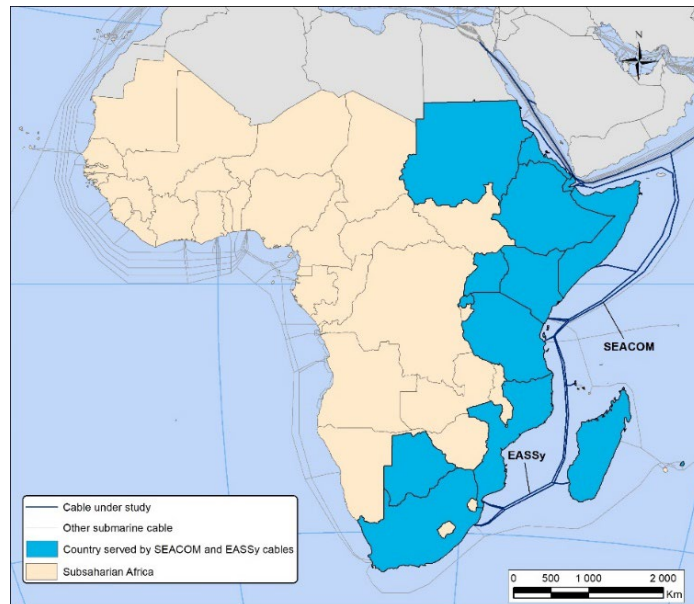


2022



Source: Telegeography's submarine cable map: <https://www.submarinecablemap.com/>

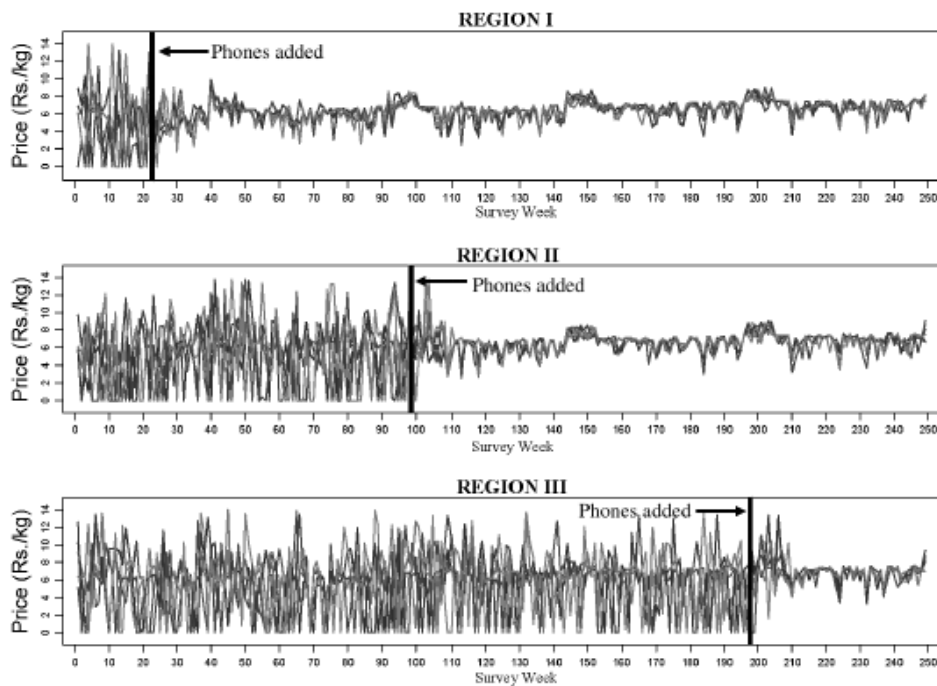
A.2. SEACOM/EASSy cables rollout in SSA.



Sources: Drawn from Cariolle (2021).

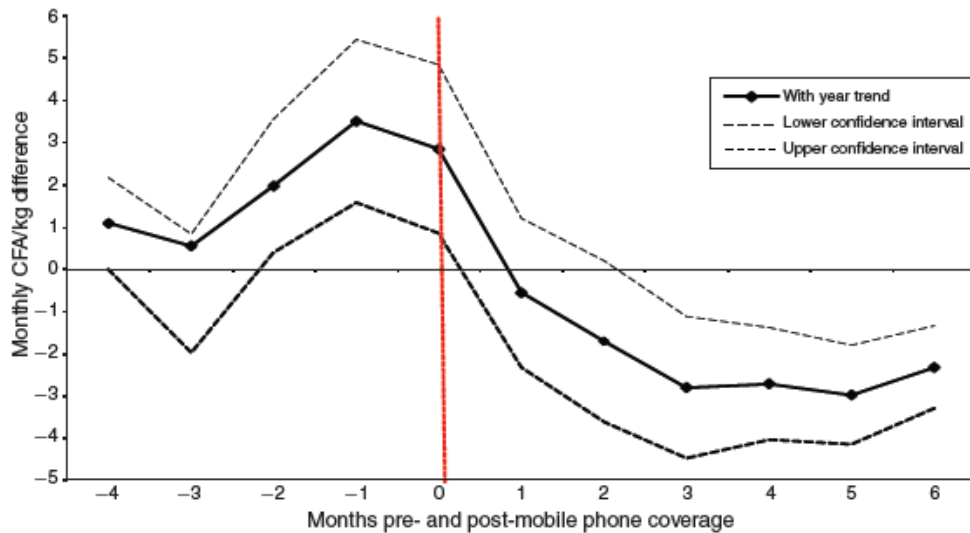
B. Mobile connectivity and market integration

B.1. Sardine prices dispersion and access to mobile phone services in Kerala, India.



Source: drawn from Jensen (2007).

B.2. Grain prices dispersion and access to the mobile network in Niger.



Source: drawn from Aker (2010).

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